Data Science Final Project

MODEL 3: CLUSTERING TECHNIQUE

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2022-12-14

Helper Packages And Modeling Packages

```
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(ggplot2)
library(stringr)
library(cluster)
library(factoextra)
```

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

```
library(gridExtra)
```

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

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

```
library(tidyverse)
```

```
## -- Attaching packages --------------------------------------- tidyverse 1.3.2 --
```

```
## v tibble  3.1.8     v purrr   0.3.5
## v tidyr   1.2.1     v forcats 0.5.2
## v readr   2.1.3
## -- Conflicts --------------------------------------- tidyverse_conflicts() --
## x gridExtra::combine() masks dplyr::combine()
## x dplyr::filter()      masks stats::filter()
## x dplyr::lag()         masks stats::lag()
```

```
library(readr)
library(mclust)
```

```
## Package 'mclust' version 6.0.0
## Type 'citation("mclust")' for citing this R package in publications.
##
## Attaching package: 'mclust'
##
## The following object is masked from 'package:purrr':
##
##     map
```

IMPORTING THE DATA

```
set.seed(123)
radiomics_data <- read_csv("D:/1 MASTERS/STAT225/FINAL PROJECT/STAT 325 _FINAL PROJECT_/Normalize Radion
```

```
## Rows: 197 Columns: 431
## -- Column specification --------------------------------------------------------
## Delimiter: ","
## chr   (1): Institution
## dbl (430): Failure.binary, Failure, Entropy_cooc.W.ADC, GLNU_align.H.PET, Mi...
##
## i Use `spec()` to retrieve the full column specification for this data.
## i Specify the column types or set `show_col_types = FALSE` to quiet this message.
```

Below are the first 6 of the data.

```
head(radiomics_data)
```

```
## # A tibble: 6 x 431
##   Institution Failure.~1 Failure Entro~2 GLNU_~3 Min_h~4 Max_h~5 Mean_~6 Varia~7
##   <chr>            <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>   <dbl>
## 1 A                    0   1.15     12.9  -0.433  -0.270 -0.257   -0.192  0.0509
## 2 A                    1  -0.533    12.2  -1.02    0.671  0.405    0.490  0.687
## 3 A                    0   2.24     12.8   0.179  -1.41  -1.57    -1.53  -1.57
## 4 A                    1  -0.140    13.5   2.00   -0.218  0.0764  -0.153  0.0127
## 5 A                    0   0.787    12.6   0.153  -1.06  -1.15    -1.45  -1.91
## 6 A                    1  -2.80     13.2   0.391  -1.57  -1.91    -1.72  -1.84
## # ... with 422 more variables: Standard_Deviation_hist.PET <dbl>,
## #   Skewness_hist.PET <dbl>, Kurtosis_hist.PET <dbl>, Energy_hist.PET <dbl>,
## #   Entropy_hist.PET <dbl>, AUC_hist.PET <dbl>, H_suv.PET <dbl>,
```

```
## #   Volume.PET <dbl>, X3D_surface.PET <dbl>, ratio_3ds_vol.PET <dbl>,
## #   ratio_3ds_vol_norm.PET <dbl>, irregularity.PET <dbl>,
## #   tumor_length.PET <dbl>, Compactness_v1.PET <dbl>, Compactness_v2.PET <dbl>,
## #   Spherical_disproportion.PET <dbl>, Sphericity.PET <dbl>, ...
```

scaling/standardizing the data

```
radiomics_data <- radiomics_data[c(3:431)]
```

```
sum(is.na(radiomics_data))
```

```
## [1] 0
```

Since there is no N/A's, we can proceed with the clustering.

#CLUSTERS

K means clustering

```
kmeans(radiomics_data, centers = 3, iter.max = 100, nstart = 100)
```

```
## K-means clustering with 3 clusters of sizes 44, 103, 50
##
## Cluster means:
##       Failure Entropy_cooc.W.ADC GLNU_align.H.PET Min_hist.PET Max_hist.PET
## 1 -0.24619905           12.33268      0.126606986   0.04582414   0.08498506
## 2  0.06533738           12.23104     -0.009427189  -0.43614178  -0.46164331
## 3  0.08209356           12.32898     -0.091994139   0.85812682   0.87619837
##   Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET Skewness_hist.PET
## 1    0.08473313         0.2277805                  0.04100243        -0.5424529
## 2   -0.45835946        -0.3328592                 -0.43567962        -0.1562938
## 3    0.86965533         0.4852431                  0.86141787         0.7993239
##   Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET AUC_hist.PET  H_suv.PET
## 1       -0.06873937      -1.2397463       -0.1534404  -1.20290321 -0.1720189
## 2        0.04875016       0.1318335       -0.5421416  -0.09783915 -0.3528293
## 3       -0.03993469       0.8193998        1.2518393   1.26010348  0.8782050
##   Volume.PET X3D_surface.PET ratio_3ds_vol.PET ratio_3ds_vol_norm.PET
## 1  0.4515175       0.1228859      -1.031642260             -0.9243764
## 2 -0.4469966      -0.3135307      -0.002503013             -0.0514460
## 3  0.5234776       0.5377336       0.913001395              0.9194300
##   irregularity.PET tumor_length.PET Compactness_v1.PET Compactness_v2.PET
## 1       -0.9580603       -0.3146062        -1.06054229       0.0007560935
## 2       -0.2024322       -0.3575160        -0.04050121      -0.3312421924
## 3        1.2601035        1.0133370         1.01671038       0.6816947970
##   Spherical_disproportion.PET Sphericity.PET Asphericity.PET Center_of_mass.PET
## 1                  -0.9243764    0.008385093     -0.92270228         -0.1662871
## 2                  -0.0514460   -0.408748277     -0.04630539         -0.2828044
## 3                   0.9194300    0.834642568      0.90736711          0.7289097
##   Max_3D_diam.PET Major_axis_length.PET Minor_axis_length.PET
```

```
## 1       0.4046184             0.2921464            0.09507154
## 2      -0.5662795            -0.5482485           -0.54506409
## 3       0.8104716             0.8723031            1.03916907
##   Least_axis_length.PET Elongation.PET Flatness.PET Max_cooc.L.PET
## 1             0.2609288     -0.8077720   -0.5658959     -1.2368186
## 2            -0.5442359     -0.2537675   -0.3405795      0.1175010
## 3             0.8915085      1.2336004    1.1995823      0.8463483
##   Average_cooc.L.PET Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET
## 1         -0.4955642          -0.6734268         -0.2683455      -0.6448461
## 2         -0.3623110          -0.1757674         -0.4970677      -0.2723810
## 3          1.1824572           0.9546964          1.2601035       1.1285694
##   DVAR_cooc.L.PET DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET
## 1      -0.6762875      -0.7051941      -0.4938394      -0.6635562
## 2      -0.1908866      -0.3104527      -0.3629185      -0.1976191
## 3       0.9883594       1.2601035       1.1821908       0.9910248
##   SENT_cooc.L.PET ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## 1      -0.9310482     -1.2286049          -0.5543879               -0.6448461
## 2      -0.2139714      0.1318891          -0.1506873               -0.2723810
## 3       1.2601035      0.8094807           0.7982773                1.1285694
##   Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## 1          -0.7769917               -0.8136118     -0.8851310
## 2          -0.2737576               -0.2641384     -0.1967642
## 3           1.2476933                1.2601035      1.1842495
##   IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## 1          -0.9668136         -0.9006801             -0.3583977
## 2          -0.1986930         -0.1926182             -0.3347999
## 3           1.2601035          1.1893919              1.0050778
##   Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## 1                 -0.4279069          -0.6635562      -0.37662109
## 2                 -0.2521613          -0.1976191      -0.06384699
## 3                  0.8960104           0.9910248       0.46295135
##   Prominence_cooc.L.PET  IC1_.L.PET IC2_.L.PET Coarseness_vdif_.L.PET
## 1           -0.64429095 -0.02864872 -1.0005069             -1.2467745
## 2           -0.06485971  0.28929559 -0.1824053              0.1388886
## 3            0.70058703 -0.57073804  1.2562010              0.8110514
##   Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## 1          -0.70538289            0.2285534             -0.8090014
## 2          -0.02509042           -0.3707759             -0.1974261
## 3           0.67242321            0.5626713              1.1186189
##   Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
## 1           -0.8797615     -1.28600130      -0.7769197        0.4271735
## 2            0.1337268     -0.06234094      -0.2798127       -0.3993524
## 3            0.4987130      1.26010348       1.2601035        0.4467533
##   RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## 1        0.4741659    -1.27752719    -1.1293148105       -0.4397308
## 2       -0.4020416    -0.06596095     0.0003066527       -0.2605452
## 3        0.4109397     1.26010348     0.9931653287        0.9236862
##   LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## 1       -1.13704860        -0.4544490     -1.0938526389        -0.3818739
## 2        0.00150105        -0.2532377     -0.0002880775        -0.2914542
## 3        0.99751061         0.9215848      0.9631837619         0.9364447
##   GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## 1           -1.28913655           -1.22301869        -0.6236610
## 2            0.05022954           -0.08924613        -0.2126497
```

```
## 3           1.03096731           1.26010348         0.9868800
##   RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET  LGLZE.L.PET
## 1       -1.10120014          -0.3046051 -1.1695429 -0.2558248 -1.140945043
## 2       -0.02323398          -0.4815782 -0.1120901 -0.4485566 -0.002220365
## 3        1.01691811           1.2601035  1.2601035  1.1491524  1.008605590
##   HGLZE.L.PET  SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET GLNU_area.L.PET
## 1  -0.4543853 -1.169002746  -0.5172963 -0.92951089  -0.2704267       0.4164200
## 2  -0.2601593  0.001671419  -0.2327100 -0.02472047  -0.3085215      -0.4001837
## 3   0.9357872  1.025279294   0.9346034  0.86889376   0.8735299       0.4579289
##   ZSNU.L.PET  ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET GLVAR_area.L.PET
## 1  0.4712947 -1.0700979     -1.28758586      -1.0104268       -0.6375918
## 2 -0.4102506 -0.1545715      0.04986928      -0.1800621       -0.2146953
## 3  0.4303770  1.2601035      1.03034483       1.2601035        1.0033531
##   ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET Average_cooc.H.PET
## 1  -0.5201697         -0.2298400     -1.0439220         -0.8667845
## 2  -0.2132431         -0.5135166      0.1787787         -0.2414238
## 3   0.8970301          1.2601035      0.5503672          1.2601035
##   Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET DVAR_cooc.H.PET
## 1          -0.1075906         -0.1512476      -0.3368512      -0.3489379
## 2          -0.5534078         -0.5127561      -0.4670489      -0.4579410
## 3           1.2346999          1.1893755       1.2585499       1.2504238
##   DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET SENT_cooc.H.PET
## 1      -0.1765452      -0.7370141      -0.2179443      -0.7925095
## 2      -0.5101347      -0.2968597      -0.5086056      -0.1373389
## 3       1.2062372       1.2601035       1.2395185       0.9803265
##   ASM_cooc.H.PET Contrast_cooc.H.PET Dissimilarity_cooc.H.PET
## 1     -1.1500618          -0.3225785               -0.3368512
## 2      0.2172291          -0.4438519               -0.4670489
## 3      0.5645624           1.1982041                1.2585499
##   Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET IDM_cooc.H.PET
## 1          -0.9444524               -1.1622969    -0.92210693
## 2          -0.1145474               -0.1151856    -0.05599947
## 3           1.0670858                1.2601035     0.92681301
##   IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET Correlation_cooc.H.PET
## 1         -1.23089598         -1.13861682             -0.2937629
## 2         -0.08588108          0.03014244             -0.3674791
## 3          1.26010348          0.93988938              1.0155183
##   Autocorrelation_cooc.H.PET Tendency_cooc.H.PET Shade_cooc.H.PET
## 1                 -0.8758287         -0.08212314       0.01301747
## 2                 -0.2311291         -0.55484894       0.28955287
## 3                  1.2468553          1.21525719      -0.60793428
##   Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET Coarseness_vdif.H.PET
## 1            0.05657518  -0.5767901  -0.3672377            -1.2288138
## 2           -0.47574640   0.3320062  -0.4234805             0.1365392
## 3            0.93025143  -0.1763575   1.1955390             0.8000853
##   Contrast_vdif.H.PET Busyness_vdif.H.PET Complexity_vdif.H.PET
## 1         -0.56946460           0.5441468           -0.91557198
## 2         -0.05874494          -0.4356625           -0.07505258
## 3          0.62214341           0.4186155            0.96031165
##   Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET RLNU_align.H.PET
## 1          -0.9370565      -0.5654173      -0.7052421        0.5000366
## 2           0.2374769      -0.3701632      -0.2153213       -0.4136037
## 3           0.3354073       1.2601035       1.0641749        0.4119913
##   RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET LGSRE_align.H.PET
```

```
## 1     -0.5198775       -1.1991256       -0.7736121        -1.1999048
## 2     -0.3896171        0.1184110       -0.2735091         0.1187439
## 3      1.2601035        0.8113038        1.2442073         0.8113038
##   HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET GLNU_norm_align.H.PET
## 1        -0.6712253        -1.1990100        -0.5793873           -1.02059613
## 2        -0.3249637         0.1172528        -0.1800196            0.03756653
## 3         1.2601035         0.8135873         0.8807012            0.82073753
##   RLNU_norm_align.H.PET GLVAR_align.H.PET RLVAR_align.H.PET Entropy_align.H.PET
## 1            -0.4211417       -0.07605649       -0.66403304         -0.09440151
## 2            -0.4317955       -0.54757978       -0.01909491         -0.57137386
## 3             1.2601035        1.19494406        0.62368460          1.26010348
##   SZSE.H.PET  LZSE.H.PET LGLZE.H.PET HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET
## 1 -0.4467099 -0.27138729  -1.1989792  -0.6197406  -1.2012727  -0.4710644
## 2 -0.4030065 -0.07461144   0.1185232  -0.3368316   0.1195423  -0.3805777
## 3  1.2232981  0.39252039   0.8109439   1.2392449   0.8108628   1.1985268
##   LZLGE.H.PET  LZHGE.H.PET GLNU_area.H.PET ZSNU.H.PET  ZSP.H.PET
## 1  -0.9505149 -0.403462890       0.4027853  0.4708721 -0.2761913
## 2   0.1834368  0.002522648      -0.4063182 -0.3657920 -0.3878684
## 3   0.4585734  0.349850687       0.4825644  0.3391641  1.0420572
##   GLNU_norm.H.PET ZSNU_norm.H.PET GLVAR_area.H.PET ZSVAR_H.PET
## 1     -1.00764207      -0.3164794       -0.1075251 -0.40788949
## 2      0.01917366      -0.3840552       -0.5267189  0.02642073
## 3      0.84722728       1.0696557        1.1796629  0.30451604
##   Entropy_area.H.PET Max_cooc.W.PET Average_cooc.W.PET Variance_cooc.W.PET
## 1        -0.05105993     -1.2459112          0.1121741           0.2335546
## 2        -0.58988871      0.2202280         -0.4613212          -0.3253769
## 3         1.26010348      0.6427321          0.8516085           0.4647485
##   Entropy_cooc.W.PET DAVE_cooc.W.PET DVAR_cooc.W.PET DENT_cooc.W.PET
## 1         -0.1072905     0.006738718       0.1970246      -0.1803521
## 2         -0.5584923    -0.424119492      -0.3222303      -0.5229929
## 3          1.2449097     0.867756082       0.4904128       1.2360752
##   SAVE_cooc.W.PET SVAR_cooc.W.PET SENT_cooc.W.PET ASM_cooc.W.PET
## 1       0.1156181       0.2549118      -0.3617410     -1.2634130
## 2      -0.4622211      -0.3284163      -0.4561071      0.1984999
## 3       0.8504316       0.4522152       1.2579126      0.7028941
##   Contrast_cooc.W.PET Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET
## 1           0.1721288              0.006738718          -0.9375557
## 2          -0.3223858             -0.424119492          -0.1655483
## 3           0.5126415              0.867756082           1.1660786
##   Inv_diff_norm_cooc.W.PET IDM_cooc.W.PET IDM_norm_cooc.W.PET
## 1               -0.8558238    -0.90988988          -0.9828363
## 2               -0.2461061    -0.08797305          -0.1918482
## 3                1.2601035     0.98192759           1.2601035
##   Inv_var_cooc.W.PET Correlation_cooc.W.PET Autocorrelation_cooc.W.PET
## 1         -0.9370922             -0.3426602                  0.3143182
## 2         -0.1190777             -0.3422077                 -0.3619782
## 3          1.0699412              1.0064888                  0.4690750
##   Tendency_cooc.W.PET Shade_cooc.W.PET Prominence_cooc.W.PET IC1_d.W.PET
## 1           0.2549118        0.2259899             0.3337971  -0.6258080
## 2          -0.3284163       -0.1930359            -0.2585297   0.3870571
## 3           0.4522152        0.1987828             0.2388296  -0.2466266
##   IC2_d.W.PET Coarseness_vdif.W.PET Contrast_vdif.W.PET Busyness_vdif.W.PET
## 1  -0.4866597            -1.2485044          -0.3595673          -0.1344966
## 2  -0.3970734             0.1742902          -0.2217484          -0.1646606
```

```
## 3   1.2462317             0.7396460           0.7732209           0.4575578
##   Complexity_vdif.W.PET Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET
## 1             0.2966242         -0.41636860      -0.7713867      -0.7984492
## 2            -0.3064288         -0.09767275      -0.2821763      -0.2476012
## 3             0.3702140          0.56761023       1.2601035       1.2126937
##   GLNU_align.W.PET RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET
## 1        0.2964473        0.4903783     -0.6838744      -0.99421758
## 2       -0.3661553       -0.4103442     -0.3195602       0.04873235
## 3        0.4934063        0.4137762      1.2601035       0.77452284
##   HGRE_align.W.PET LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET
## 1        0.3171582       -1.01360410         0.3118848       -0.89164937
## 2       -0.3648013        0.03592996        -0.3575084        0.07771776
## 3        0.4723914        0.81795589         0.4620087        0.62455287
##   HGLRE_align.W.PET GLNU_norm_align.W.PET RLNU_norm_align.W.PET
## 1         0.3285020           -1.14436073            -0.5348833
## 2        -0.3794703            0.09070163            -0.3832069
## 3         0.4926271            0.82019209             1.2601035
##   GLVAR_align.W.PET RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET
## 1         0.2469658       -0.88171590         -0.08897816 -0.5458488
## 2        -0.3400889        0.03912658         -0.57369063 -0.3785226
## 3         0.4832532        0.69530904          1.26010348  1.2601035
##    LZSE.W.PET LGLZE.W.PET HGLZE.W.PET SZLGE.W.PET SZHGE.W.PET LZLGE.W.PET
## 1 -0.57423830 -1.00060806   0.3030741 -1.08553622   0.2676319  -0.7098443
## 2 -0.05493204  0.03609125  -0.3612973  0.01377567  -0.3411788   0.1221971
## 3  0.61848970  0.80618711   0.4775674  0.92689401   0.4673123   0.3729370
##   LZHGE.W.PET GLNU_area.W.PET ZSNU.W.PET  ZSP.W.PET GLNU_norm.W.PET
## 1   0.2910763       0.3497735  0.4790935 -0.4311684     -1.14171833
## 2  -0.3855402      -0.3914134 -0.3951841 -0.4241199      0.07906742
## 3   0.5380657       0.4985108  0.3924770  1.2531151      0.84183325
##   ZSNU_norm.W.PET GLVAR_area.W.PET ZSVAR.W.PET Entropy_area.W.PET Min_hist.ADC
## 1      -0.3987918        0.2290786 -0.57384578        -0.05587383   -0.2839460
## 2      -0.4342701       -0.3293288  0.05364306        -0.58783229   -0.1360750
## 3       1.2455332        0.4768281  0.39447957         1.26010348    0.5356019
##   Max_hist.ADC Mean_hist.ADC Variance_hist.ADC Standard_Deviation_hist.ADC
## 1   -0.4635840    -0.3889453       -0.57324808                   -0.6677390
## 2   -0.4109585    -0.4404749       -0.09465534                   -0.2637073
## 3    1.2549000     1.2496503        0.69944832                    1.1308474
##   Skewness_hist.ADC Kurtosis_hist.ADC Energy_hist.ADC Entropy_hist.ADC
## 1       -0.06412824        0.05489374      -1.2248338       -0.4447917
## 2       -0.18754348       -0.16659367       0.1306280       -0.4216926
## 3        0.44277242        0.29487646       0.8087608        1.2601035
##   AUC_hist.ADC Volume.ADC X3D_surface.ADC ratio_3ds_vol.ADC
## 1   -0.8187563  0.4137352     -0.06062747        -0.7495328
## 2   -0.2619403 -0.4230570     -0.27514913        -0.1973241
## 3    1.2601035  0.5074105      0.62015938         1.0660761
##   ratio_3ds_vol_norm.ADC irregularity.ADC Compactness_v1.ADC Compactness_v2.ADC
## 1             -0.5665482       -0.6588633        -1.27996576         -0.7091030
## 2             -0.3696801       -0.3302445         0.03139817         -0.2320236
## 3              1.2601035        1.2601035         1.06168964          1.1019793
##   Spherical_disproportion.ADC Sphericity.ADC Asphericity.ADC Center_of_mass.ADC
## 1                  -0.5665482     -0.8263138      -0.4562283        -0.30889853
## 2                  -0.3696801     -0.2587123      -0.3555244        -0.08723432
## 3                   1.2601035      1.2601035       1.1338612         0.45153340
##   Max_3D_diam.ADC Major_axis_length.ADC Minor_axis_length.ADC
```

```
## 1      -0.2272466            -0.3096826            -0.2273920
## 2      -0.3641393            -0.4002567            -0.3810801
## 3       0.9501040             1.0970495             0.9851300
##   Least_axis_length.ADC Elongation.ADC Flatness.ADC Max_cooc.L.ADC
## 1            -0.1584101     -0.4555603   -0.4352743    -1.21898466
## 2            -0.3766661     -0.4154356   -0.4102787     0.08247576
## 3             0.9153330      1.2566904    1.2282154     0.90280642
##   Average_cooc.L.ADC Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC
## 1         -0.3334022          -0.6739796         -0.6246132      -0.6275483
## 2         -0.4657713          -0.1418733         -0.3448756      -0.2975032
## 3          1.2528828           0.8853611          1.2601035       1.1650991
##   DVAR_cooc.L.ADC DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC
## 1      -0.6792861      -0.7163919      -0.3331065      -0.6644654
## 2      -0.1346799      -0.3056692      -0.4658976      -0.1328135
## 3       0.8752124       1.2601035       1.2528828       0.8583253
##   SENT_cooc.L.ADC ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## 1      -0.3986302     -1.2078330          -0.5907004               -0.6275483
## 2      -0.3227867      0.1096301          -0.1425577               -0.2975032
## 3       1.0157352      0.8370442           0.8134852                1.1650991
##   Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## 1          -0.8106287                -1.033224     -0.8257846
## 2          -0.2643399                -0.170323     -0.2353613
## 3           1.2578935                 1.260102      1.2115347
##   IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## 1          -1.1864475         -0.8125180              -0.6732339
## 2          -0.1048688         -0.2448072              -0.2079255
## 3           1.2601035          1.2193186               1.0207723
##   Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC Prominence_cooc.L.ADC
## 1             -0.3096152          -0.6644654  -0.06131213          -0.632012951
## 2             -0.3806305          -0.1328135  -0.08926511           0.009639142
## 3              1.0565602           0.8583253   0.23784081           0.536314765
##   IC1_.L.ADC IC2_.L.ADC Coarseness_vdif_.L.ADC Contrast_vdif_.L.ADC
## 1 -0.3286775 -0.8504159             -1.2306293          -0.75531507
## 2  0.4221620 -0.2429369              0.1831016          -0.00426411
## 3 -0.5804176  1.2488160              0.7057617           0.67346133
##   Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC Strength_vdif_.L.ADC
## 1           -0.4833384             -0.6202209          -0.35760129
## 2           -0.1266996             -0.2878726          -0.04138263
## 3            0.6863390              1.1388120           0.39993735
##   SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC RLNU_align.L.ADC
## 1     -1.22833517      -0.7704476      0.009702583      -0.04684558
## 2     -0.08697493      -0.2825775     -0.240760507      -0.22537592
## 3      1.26010162       1.2601035      0.487428372       0.50549851
##   RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC LGSRE_align.L.ADC
## 1     -1.1846756       -1.2386718       -0.3621041        -1.2384754
## 2     -0.1056257        0.1448884       -0.3944579         0.1441628
## 3      1.2601035        0.7915610        1.1312349         0.7928837
##   HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC GLNU_norm_align.L.ADC
## 1        -0.3718172        -1.2402380        -0.3207144           -1.22633549
## 2        -0.3912582         0.1518783        -0.4119247           -0.04113242
## 3         1.1331911         0.7785402         1.1307935            1.16390802
##   RLNU_norm_align.L.ADC GLVAR_align.L.ADC RLVAR_align.L.ADC Entropy_align.L.ADC
## 1            -1.0564678        -0.6883319        -0.9937756          -0.7413903
## 2            -0.1603942        -0.1602669        -0.0982178          -0.2949903
```

```
## 3             1.2601035         0.9358820         1.0768529           1.2601035
##   SZSE.L.ADC LZSE.L.ADC LGLZE.L.ADC HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC
## 1 -1.0514733 -0.4386766  -1.2381380  -0.3641634  -1.2347891  -0.3747242
## 2 -0.1625277 -0.3953429   0.1399974  -0.4018017   0.1376303  -0.3949377
## 3  1.2601035  1.2004418   0.8011667   1.1481754   0.8030950   1.1433289
##   LZLGE.L.ADC LZHGE.L.ADC GLNU_area.L.ADC  ZSNU.L.ADC  ZSP.L.ADC
## 1  -1.2331796  -0.2671294    -0.003032553 -0.04621719 -0.8812271
## 2   0.1872096  -0.4080677    -0.238004422 -0.22780845 -0.2352542
## 3   0.6995465   1.0756933     0.492957756  0.50995654  1.2601035
##   GLNU_norm.L.ADC ZSNU_norm.L.ADC GLVAR_area.L.ADC ZSVAR.L.ADC
## 1     -1.24380273      -0.8418370       -0.6976156  -0.3886638
## 2     -0.03057441      -0.2520807       -0.1626997  -0.1999883
## 3      1.15753016       1.2601012        0.9490632   0.7539999
##   Entropy_area.L.ADC Max_cooc.H.ADC Average_cooc.H.ADC Variance_cooc.H.ADC
## 1         -0.6968516     -1.2195763         -0.4648233          -0.3952568
## 2         -0.3140165      0.1226214         -0.4131354          -0.4428532
## 3          1.2601035      0.8206280          1.2601035           1.2601035
##   Entropy_cooc.H.ADC DAVE_cooc.H.ADC DVAR_cooc.H.ADC DENT_cooc.H.ADC
## 1         -0.2456499      -0.4106896      -0.4407048      -0.4873658
## 2         -0.5067629      -0.4362605      -0.4222198      -0.4035056
## 3          1.2601035       1.2601035       1.2575931       1.2600955
##   SAVE_cooc.H.ADC SVAR_cooc.H.ADC SENT_cooc.H.ADC ASM_cooc.H.ADC
## 1      -0.4574294      -0.5523827      -0.4826353     -1.2187170
## 2      -0.4162940      -0.3757314      -0.4055264      0.1276736
## 3       1.2601035       1.2601035       1.2601035      0.8094090
##   Contrast_cooc.H.ADC Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC
## 1          -0.3609737               -0.4106896          -1.1798197
## 2          -0.4341280               -0.4362605          -0.1075456
## 3           1.2119605                1.2601035           1.2597865
##   Inv_diff_norm_cooc.H.ADC IDM_cooc.H.ADC IDM_norm_cooc.H.ADC
## 1               -1.1769913    -1.20553484         -1.21238942
## 2               -0.1089083    -0.08629617         -0.09378679
## 3                1.2601035     1.23864077          1.26010348
##   Inv_var_cooc.H.ADC Correlation_cooc.H.ADC Autocorrelation_cooc.H.ADC
## 1         -1.2362039             -0.6754567                 -0.5592331
## 2         -0.0746561             -0.2053340                 -0.3728050
## 3          1.2416511              1.0173899                  1.2601035
##   Tendency_cooc.H.ADC Shade_cooc.H.ADC Prominence_cooc.H.ADC IC1_d.H.ADC
## 1          -0.5523827      -0.04021948            -0.5274542  -0.2930730
## 2          -0.3757314      -0.17187278            -0.3863805   0.3516626
## 3           1.2601035       0.38945107             1.2601035  -0.4665213
##   IC2_d.H.ADC Coarseness_vdif.H.ADC Contrast_vdif.H.ADC Busyness_vdif.H.ADC
## 1  -0.7745696            -1.2274857          -0.4516339          -0.2332118
## 2  -0.2794834             0.1822561          -0.4186159          -0.1961535
## 3   1.2573571             0.7047403           1.2597865           0.6093025
##   Complexity_vdif.H.ADC Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC
## 1            -0.3776594         -0.31448595     -1.28508015      -1.0977408
## 2            -0.4475287         -0.03715531     -0.06273425      -0.1427629
## 3             1.2542493          0.35328758      1.26010348       1.2601035
##   GLNU_align.H.ADC RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC
## 1      -0.05169972      -0.04863572    -1.27270722      -1.27672651
## 2      -0.22752508      -0.22997103    -0.06802005       0.03984021
## 3       0.51419743       0.51653976     1.26010348       1.04142924
##   HGRE_align.H.ADC LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC
```

```
## 1       -0.5635528       -1.27571074        -0.4692509      -1.271448876
## 2       -0.3709597        0.04334384        -0.4112440       0.007470147
## 3        1.2601035        1.03332111         1.2601035       1.103486399
##   HGLRE_align.H.ADC GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC
## 1        -0.3916857           -1.25710430           -1.20154494
## 2        -0.4443787            0.05815368           -0.09841951
## 3         1.2601035            0.98645175            1.26010348
##   GLVAR_align.H.ADC RLVAR_align.H.ADC Entropy_align.H.ADC SZSE.H.ADC LZSE.H.ADC
## 1        -0.4584233      -1.233836931          -0.7044152 -1.1327756 -0.7274341
## 2        -0.4158694       0.006015476          -0.3107856 -0.1277969 -0.3008986
## 3         1.2601035       1.073384619           1.2601035  1.2601035  1.2601035
##   LGLZE.H.ADC HGLZE.H.ADC SZLGE.H.ADC SZHGE.H.ADC LZLGE.H.ADC LZHGE.H.ADC
## 1 -1.26419521  -0.6234993 -1.25631169  -0.4625418 -1.17805121  -0.5641318
## 2  0.04239107  -0.3453515  0.05393276  -0.4141100 -0.00305751  -0.3702458
## 3  1.02516668   1.2601035  0.99445300   1.2601035  1.04298353   1.2591423
##   GLNU_area.H.ADC ZSNU.H.ADC  ZSP.H.ADC GLNU_norm.H.ADC ZSNU_norm.H.ADC
## 1     -0.04629173 -0.0380691 -0.9989990     -1.25998052      -0.8734469
## 2     -0.22985144 -0.2346340 -0.1849442      0.05936074      -0.2385781
## 3      0.51423069  0.5168978  1.2601035      0.98604257       1.2601035
##   GLVAR_area.H.ADC ZSVAR.H.ADC Entropy_area.H.ADC Max_cooc.W.ADC
## 1       -0.3959549 -0.86964158         -0.6175828     -1.2227040
## 2       -0.4425550 -0.02618112         -0.3478789      0.1289851
## 3        1.2601035  0.81922296          1.2601035      0.8102563
##   Average_cooc.W.ADC Variance_cooc.W.ADC DAVE_cooc.W.ADC DVAR_cooc.W.ADC
## 1         -0.3004989         -0.57373994      -0.6384395      -0.6111998
## 2         -0.3720482         -0.08003143      -0.2959584      -0.0907048
## 3          1.0308583          0.66975588       1.1715010       0.7247077
##   DENT_cooc.W.ADC SAVE_cooc.W.ADC SVAR_cooc.W.ADC SENT_cooc.W.ADC
## 1      -0.7144191      -0.3119314     -0.52193538      -0.3570017
## 2      -0.3065120      -0.3678297     -0.07787238      -0.3281686
## 3       1.2601035       1.0322287      0.61972023       0.9901887
##   ASM_cooc.W.ADC Contrast_cooc.W.ADC Dissimilarity_cooc.W.ADC
## 1     -1.2185004          -0.5848798               -0.6384395
## 2      0.1275774          -0.1101784               -0.2959584
## 3      0.8094624           0.7416618                1.1715010
##   Inv_diff_cooc.W.ADC Inv_diff_norm_cooc.W.ADC IDM_cooc.W.ADC
## 1          -1.0933303               -1.0324694    -1.15112454
## 2          -0.1118448               -0.1706458    -0.09016671
## 3           1.1925307                1.2601035     1.19873300
##   IDM_norm_cooc.W.ADC Inv_var_cooc.W.ADC Correlation_cooc.W.ADC
## 1           -1.183584        -1.12975006             -0.6710596
## 2           -0.106092        -0.09544937             -0.2087147
## 3            1.260103         1.19080576              1.0204847
##   Autocorrelation_cooc.W.ADC Tendency_cooc.W.ADC Shade_cooc.W.ADC
## 1                 -0.2373656         -0.52193538      -0.01897833
## 2                 -0.2456825         -0.07787238      -0.08227907
## 3                  0.7149876          0.61972023       0.18619581
##   Prominence_cooc.W.ADC IC1_d.W.ADC IC2_d.W.ADC Coarseness_vdif.W.ADC
## 1           -0.41203710 -0.09221458  -0.8157384            -1.2311552
## 2            0.02841938  0.32916605  -0.2632300             0.1693522
## 3            0.30404482 -0.59693323   1.2601035             0.7345515
##   Contrast_vdif.W.ADC Busyness_vdif.W.ADC Complexity_vdif.W.ADC
## 1         -0.67751125         -1.09459202            -0.2913541
## 2         -0.03593965         -0.01151753            -0.1147268
```

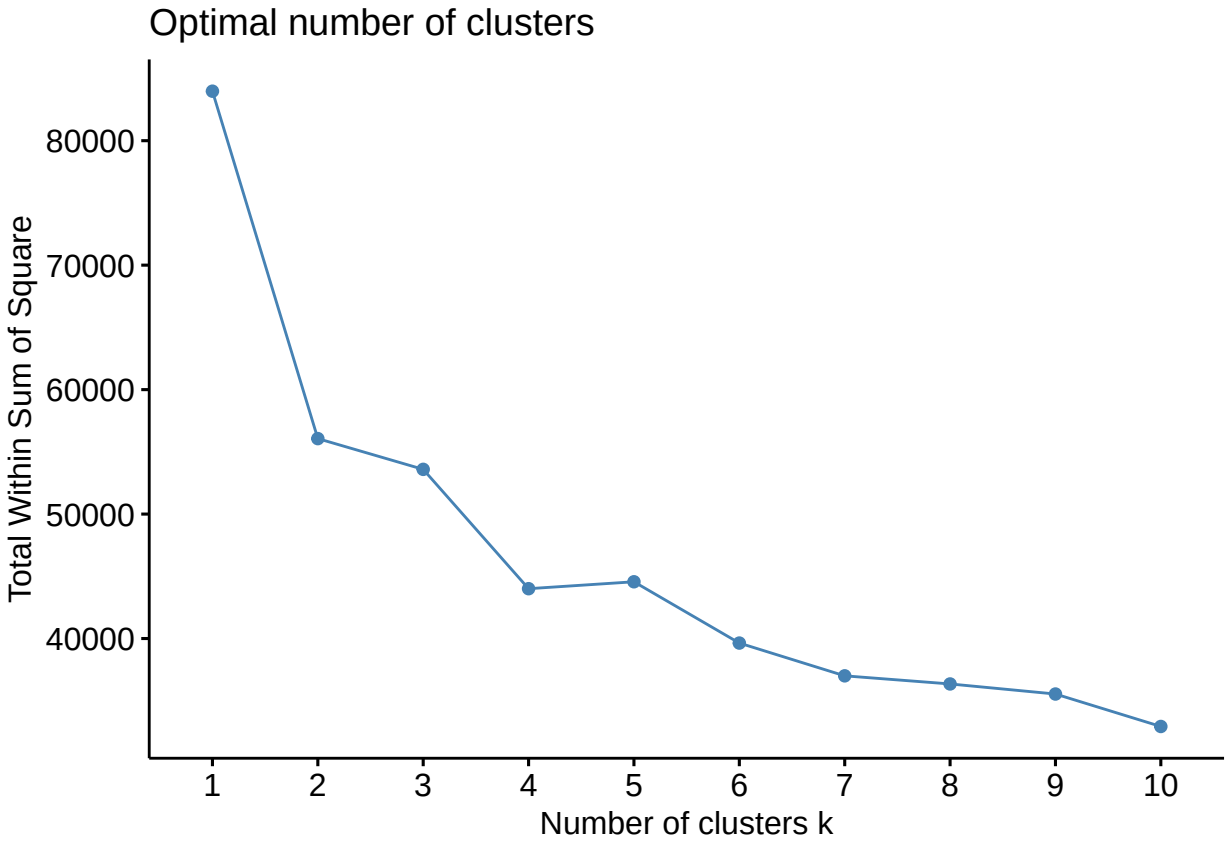
```
## 3          0.67024557          0.98696733             0.4927289
##   Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC GLNU_align.W.ADC
## 1         -0.55656938     -1.29343778      -1.1587796       0.02981081
## 2         -0.04365878     -0.05916419      -0.1166881      -0.28907241
## 3          0.57971814      1.26010348       1.2601035       0.56925565
##   RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC HGRE_align.W.ADC
## 1      -0.03892635    -1.29039489       -1.2364486       -0.2674843
## 2      -0.22807570    -0.06046407        0.1437900       -0.2416115
## 3       0.50409113     1.26010348        0.7918681        0.7331058
##   LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC HGLRE_align.W.ADC
## 1        -1.2357620        -0.2701417        -1.2374136        -0.2693989
## 2         0.1423437        -0.2403440         0.1509209        -0.2440651
## 3         0.7942434         0.7328334         0.7780140         0.7398451
##   GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC GLVAR_align.W.ADC
## 1           -1.24042618           -1.26256386       -0.57920910
## 2            0.07440259           -0.07235316       -0.09716138
## 3            0.93830670            1.26010348        0.70985644
##   RLVAR_align.W.ADC Entropy_align.W.ADC  SZSE.W.ADC LZSE.W.ADC LGLZE.W.ADC
## 1       -1.22390939          -0.4226539 -1.20929938 -0.8747723  -1.2332639
## 2        0.03268583          -0.4311495 -0.09510682 -0.2380116   0.1396824
## 3        1.00970174           1.2601035  1.26010348  1.2601035   0.7975267
##   HGLZE.W.ADC SZLGE.W.ADC SZHGE.W.ADC LZLGE.W.ADC LZHGE.W.ADC GLNU_area.W.ADC
## 1  -0.2680471  -1.2296821  -0.2693260  -1.2407187  -0.2645417      0.03293853
## 2  -0.2415063   0.1359966  -0.2401366   0.1826938  -0.2542061     -0.29214726
## 3   0.7333844   0.8019663   0.7316883   0.7154832   0.7564613      0.57283746
##    ZSNU.W.ADC  ZSP.W.ADC GLNU_norm.W.ADC ZSNU_norm.W.ADC GLVAR_area.W.ADC
## 1 -0.03035959 -1.1746353     -1.24189406       -1.074228       -0.5797675
## 2 -0.22612770 -0.1099147      0.08398451       -0.152807       -0.1003412
## 3  0.49253950  1.2601035      0.91985828        1.260103        0.7168983
##   ZSVAR.W.ADC Entropy_area.W.ADC
## 1 -1.07555535         -0.5276676
## 2 -0.03694412         -0.3862893
## 3  1.02259359          1.2601035
##
## Clustering vector:
##   [1] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [38] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
##  [75] 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 1 1 1 1 1 2 1 1 1 2 2 2 1 1 1 1 2 2 2 2 2 2
## [112] 2 1 1 2 2 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 2 1 1 1 1 1 1 1 3
## [149] 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3 3
## [186] 3 3 3 3 3 3 3 3 3 3 3 3
##
## Within cluster sum of squares by cluster:
## [1] 10400.15 24970.22 13404.39
##  (between_SS / total_SS =  41.9 %)
##
## Available components:
##
## [1] "cluster"      "centers"      "totss"        "withinss"     "tot.withinss"
## [6] "betweenss"    "size"         "iter"         "ifault"
```

```
clusters <- kmeans(radiomics_data, centers = 3, iter.max = 100, nstart = 100)
```

Clustering using kmeans has 41.9 percent with k = 3.

K means clustering using WSS

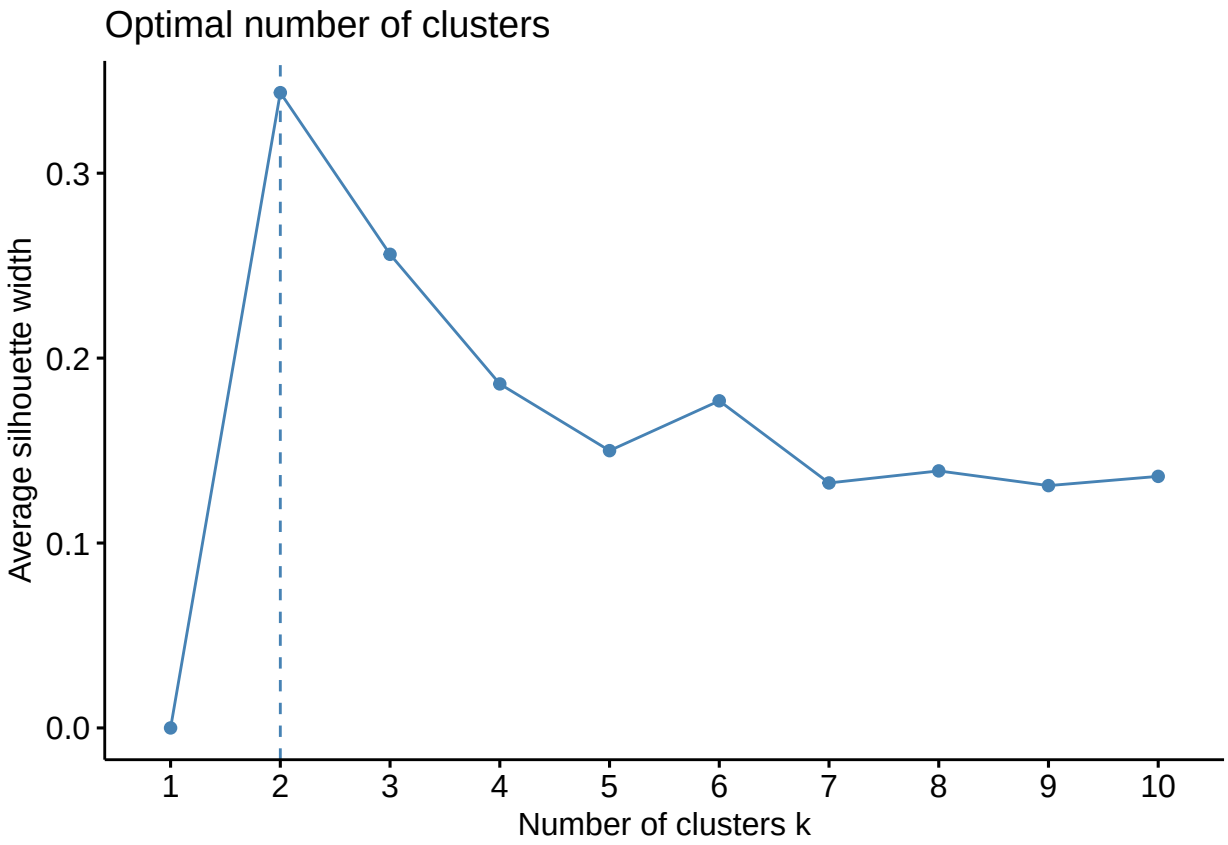
```
fviz_nbclust(radiomics_data, kmeans, method = "wss")
```



Using elbow method to identify k, k=2.

K means clustering using silhouette

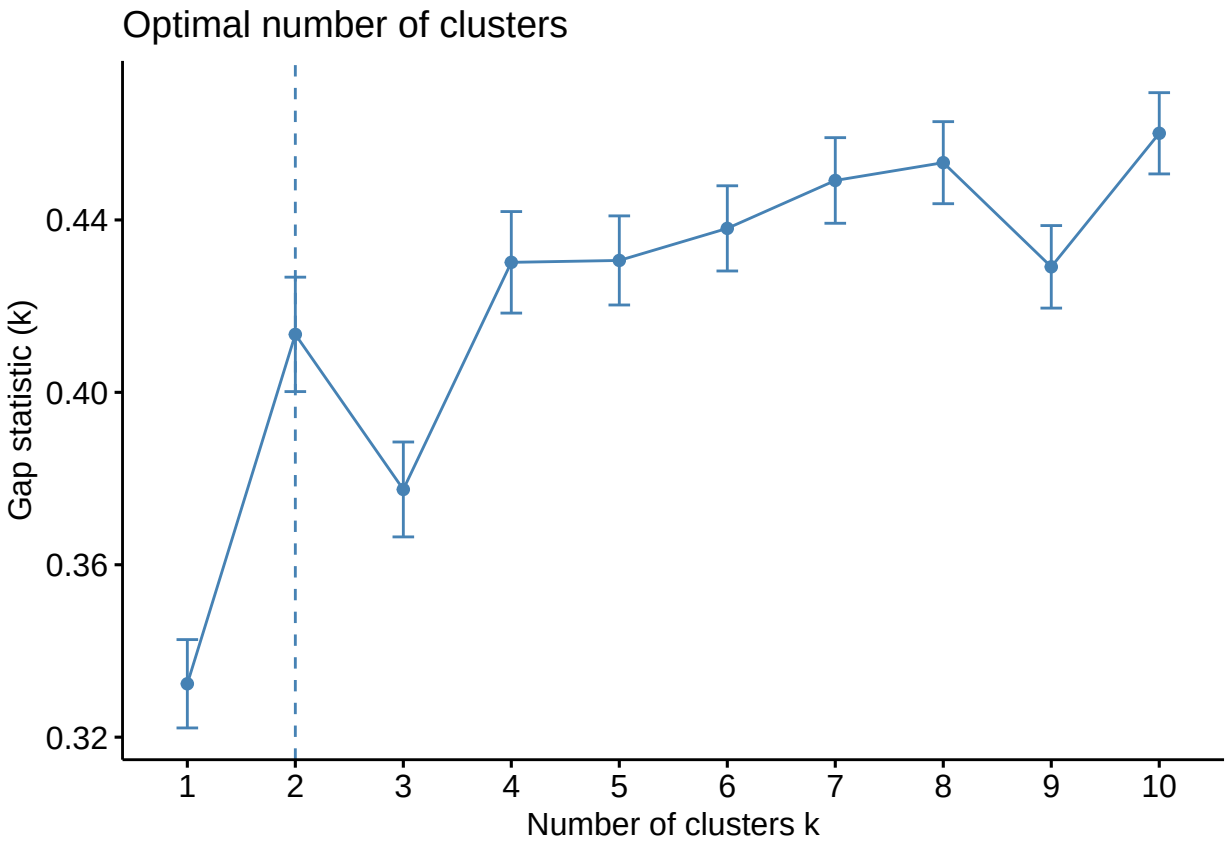
```
fviz_nbclust(radiomics_data, kmeans, method = "silhouette")
```



Silhoutte suggest that number of cluster is 2.

K means clustering using gap_stat

```
fviz_nbclust(radiomics_data, kmeans, method = "gap_stat")
```

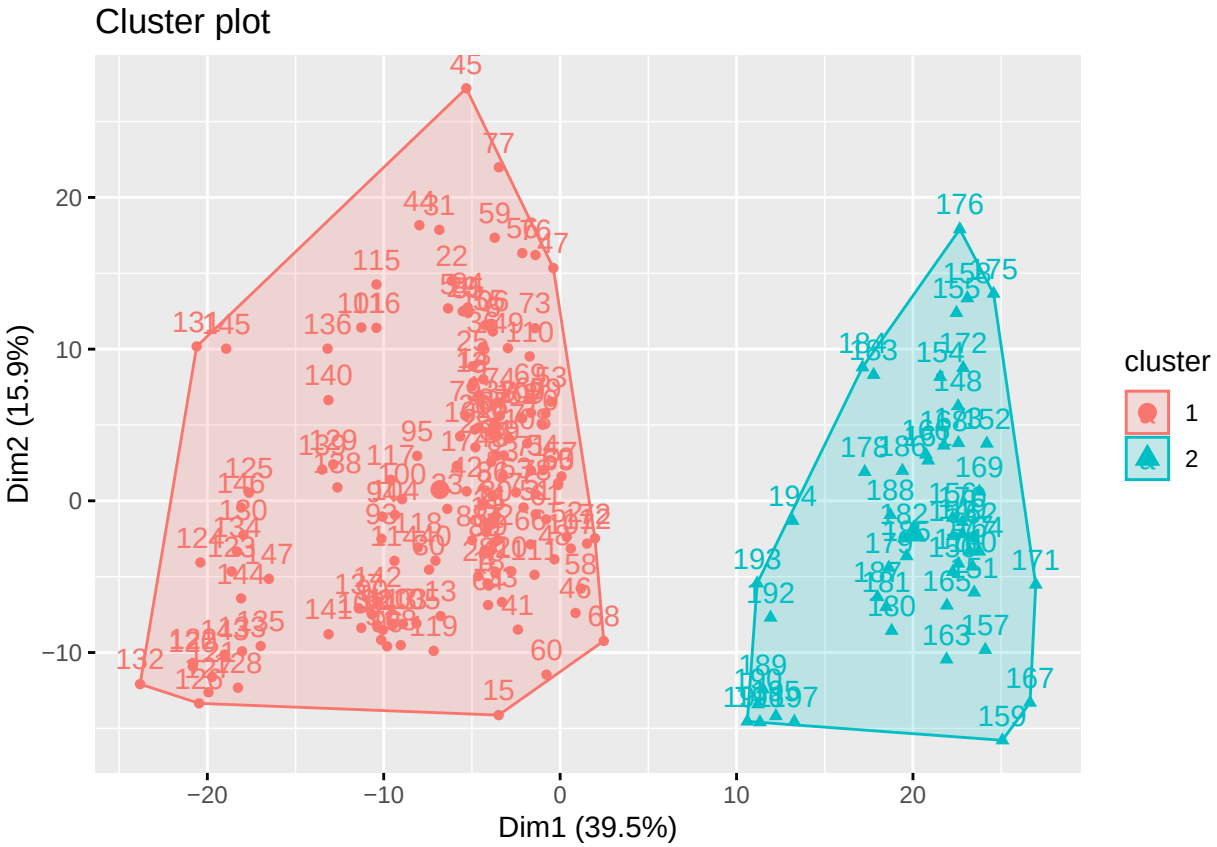


Gap-stat suggest that the number of cluster is 2.

Since cluster is equal to 2, the number of cluster is 2. Below is the cluster using 2 cluster.

```
clusters <- kmeans(radiomics_data, centers = 2, iter.max = 100, nstart = 100)
```

```
fviz_cluster(kmeans(radiomics_data, centers = 2, iter.max = 100, nstart = 100), data = radiomics_data)
```



Above image shows the cluster structure using 2 number of clusters.

The quality of a k-means partition.

```
clusters$betweenss / clusters$totss
```

```
## [1] 0.3324189
```

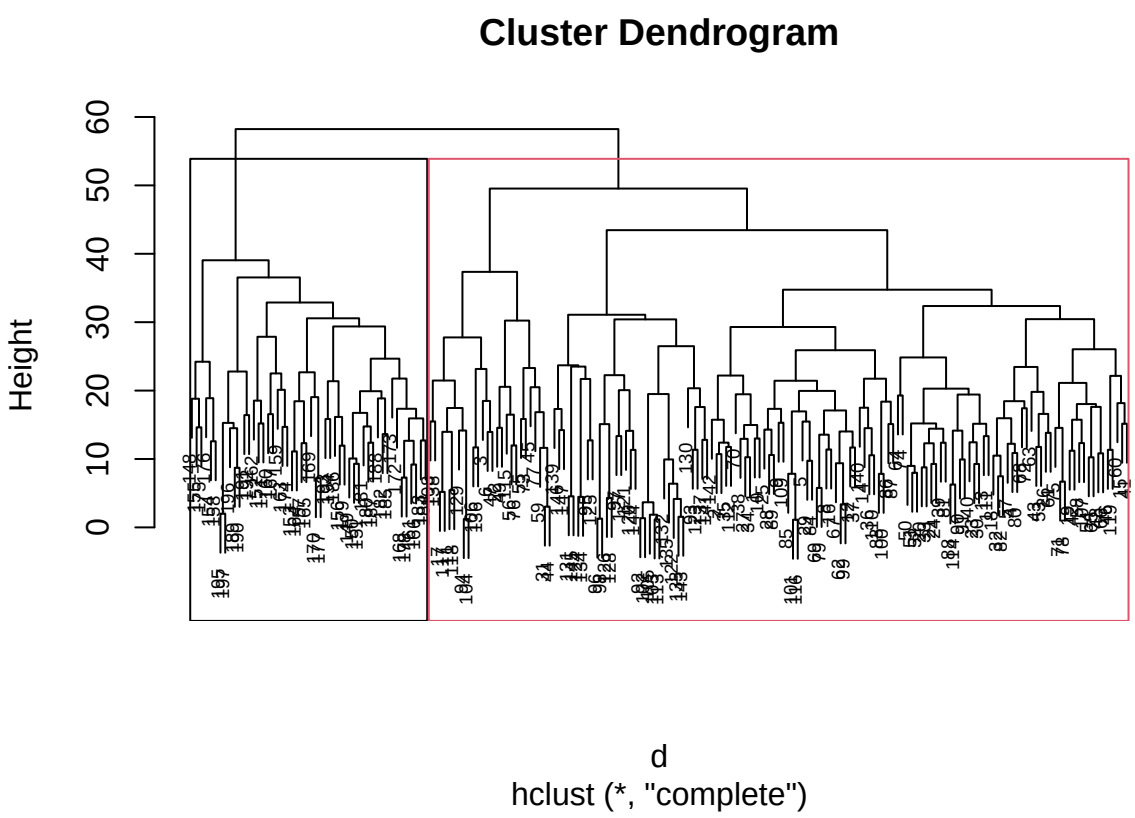
The quality of k means partition is 0.4192 or 41.92 percent.

2. Heirarchical Clustering

```
radiomics_data <- radiomics_data %>%
  select_if(is.numeric) %>%  # select numeric columns
  mutate_all(as.double) %>%  # coerce to double type
  scale()
d <- dist(radiomics_data, method = "euclidean")
```

Hierarchical clustering using Complete Linkage

```
hc1 <- hclust(d, method = "complete")
plot(hc1, cex = 0.6)
rect.hclust(hc1, k = 2, border = 1:4)
```



Hierarchical clustering using AGNES

```
set.seed(123)
hc2 <- agnes(radiomics_data, method = "complete")
hc2$ac
```

```
## [1] 0.8076961
```

Using the AGNES, it has 80.77 percent quality of partition.

Hierarchical clustering using DIANA

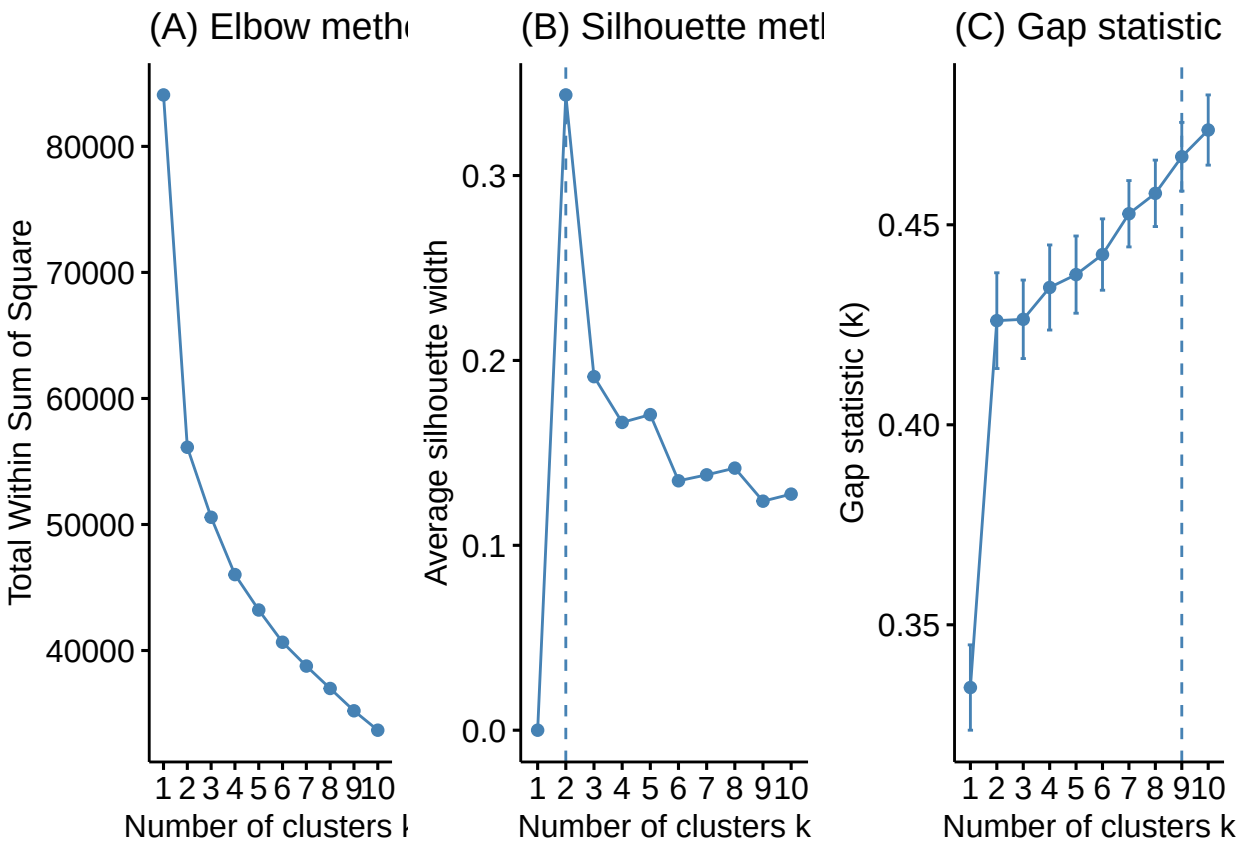
```
hc4 <- diana(radiomics_data)
hc4$dc
```

```
## [1] 0.7919039
```

Using the DIANA, it has 79.19 percent quality of partition.

```
wss_plot <- fviz_nbclust(radiomics_data, FUN = hcut, method = "wss",
                   k.max = 10) +
  ggtitle("(A) Elbow method")
silhouette_plot <- fviz_nbclust(radiomics_data, FUN = hcut, method = "silhouette",
                   k.max = 10) +
  ggtitle("(B) Silhouette method")
gapstat_plot <- fviz_nbclust(radiomics_data, FUN = hcut, method = "gap_stat",
                   k.max = 10) +
  ggtitle("(C) Gap statistic")
```

```
gridExtra::grid.arrange(wss_plot, silhouette_plot, gapstat_plot, nrow = 1)
```



The result of the graph shows that they give different number of cluster in each method. Elbow method gives 3, silhouette gives 2 and gap stat gives 9. The difference between heirarchical and k means is that k means gives the same number of cluster in gap stat, silhouette and elbow method. While in heirarchical does not.

Ward's method

```
hc5 <- hclust(d, method = "ward.D2" )
sub_grp <- cutree(hc5, k = 9)
table(sub_grp)
```

```
## sub_grp
##  1  2  3  4  5  6  7  8  9
## 25 33 46 12 21 10 19 22  9
```

Above is the number of sample in each cluster. If number of cluster is 8, the member of cluster is 22.

3. Model Based

```
set.seed(123)
model_based3 <- Mclust(radiomics_data[,1:10], G=3)
summary(model_based3)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEE (ellipsoidal, equal shape and orientation) model with 3 components:
##
##  log-likelihood   n df       BIC      ICL
##       -1074.583 197 89 -2619.371 -2638.94
##
## Clustering table:
##   1   2   3
## 111  50  36
```

The result shows 3 optimal number of clusters with BIC -2632.206. A negative zone with the highest value indicates the preferred model, In general, the lower the BIC value, the better. Plot the results with BIC, density and uncertainty.

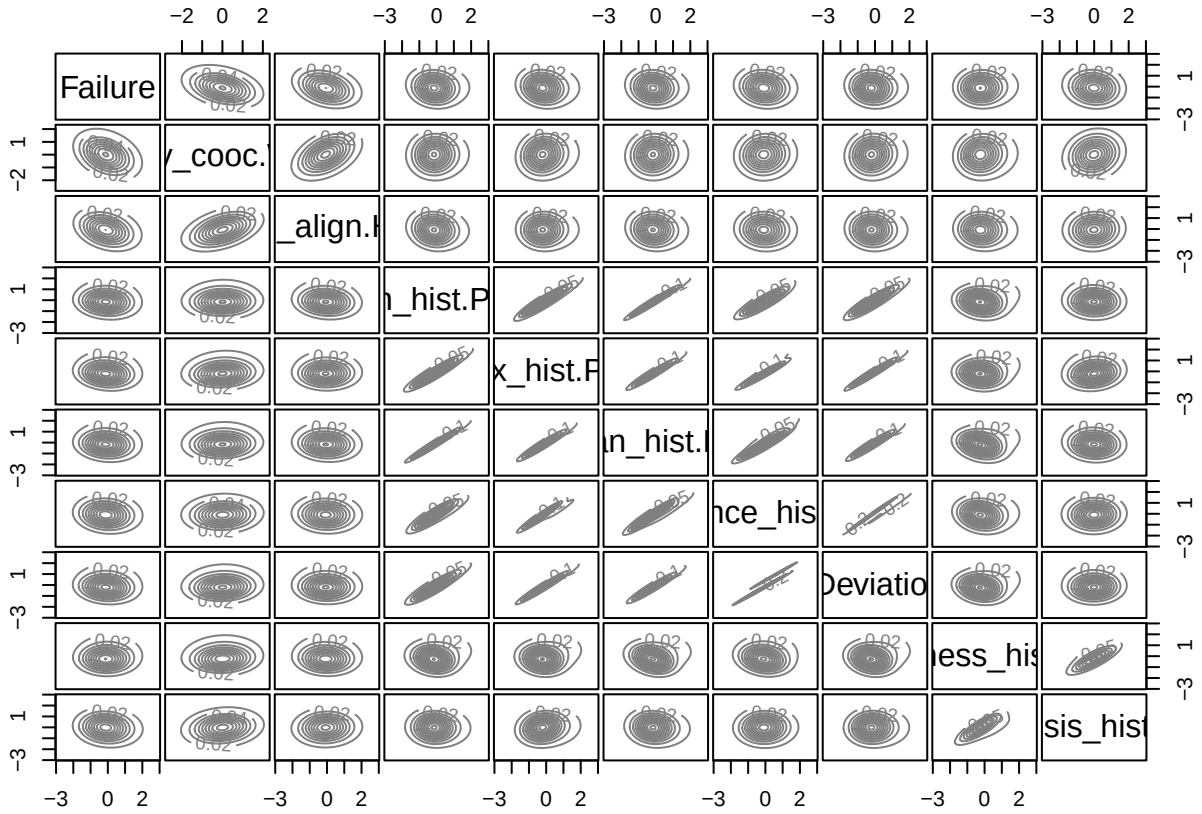
```
set.seed(123)
model_based4 = Mclust(radiomics_data, 1:9)
summary(model_based4)
```

```
## ----------------------------------------------------
## Gaussian finite mixture model fitted by EM algorithm
## ----------------------------------------------------
##
## Mclust VEI (diagonal, equal shape) model with 9 components:
##
##  log-likelihood   n   df       BIC       ICL
##       -77829.42 197 4306 -178408.3 -178408.3
##
## Clustering table:
##  1  2  3  4  5  6  7  8  9
## 32 29 25 11 21 41 19 10  9
```

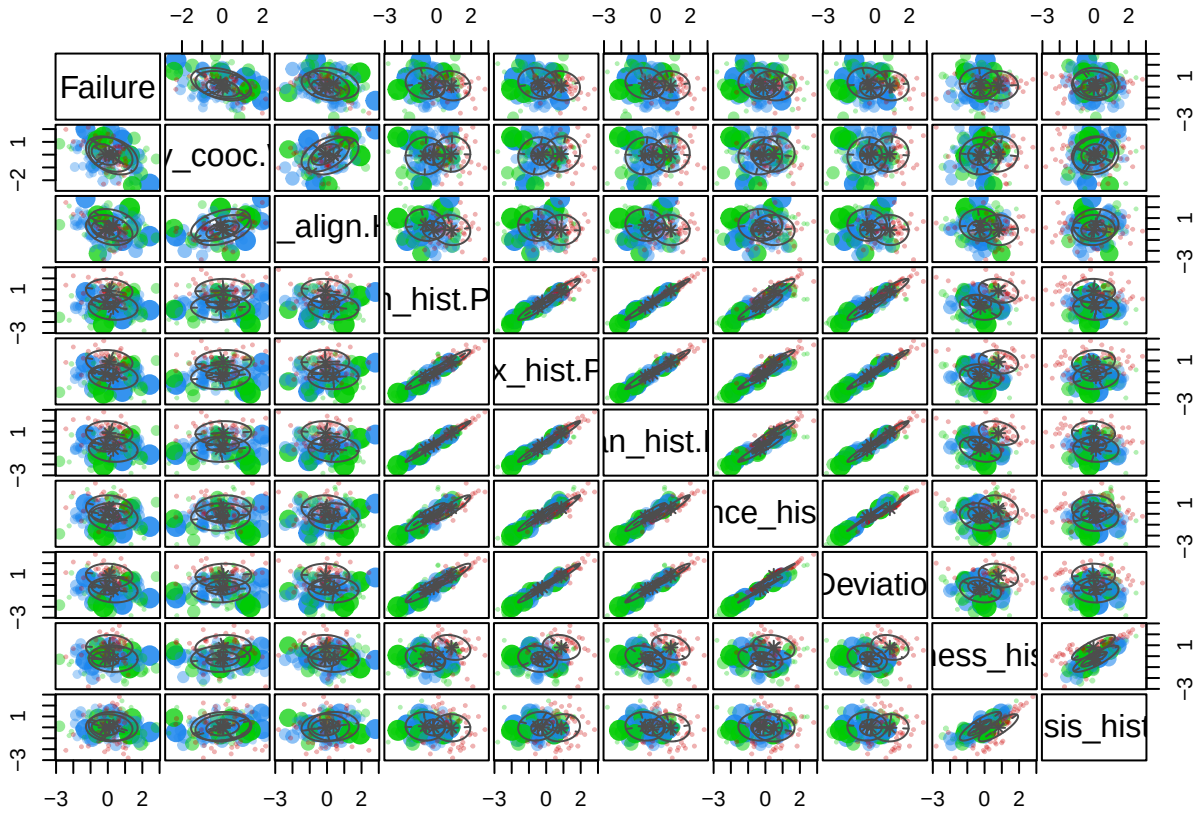
The result shows 3 optimal number of clusters with BIC -178301. A negative zone with the highest value indicates the preferred model, In general, the lower the BIC value, the better. Plot the results with BIC, density and uncertainty.

Plot results

```
plot(model_based3, what = "density")
```




```
plot(model_based3, what = "uncertainty")
```

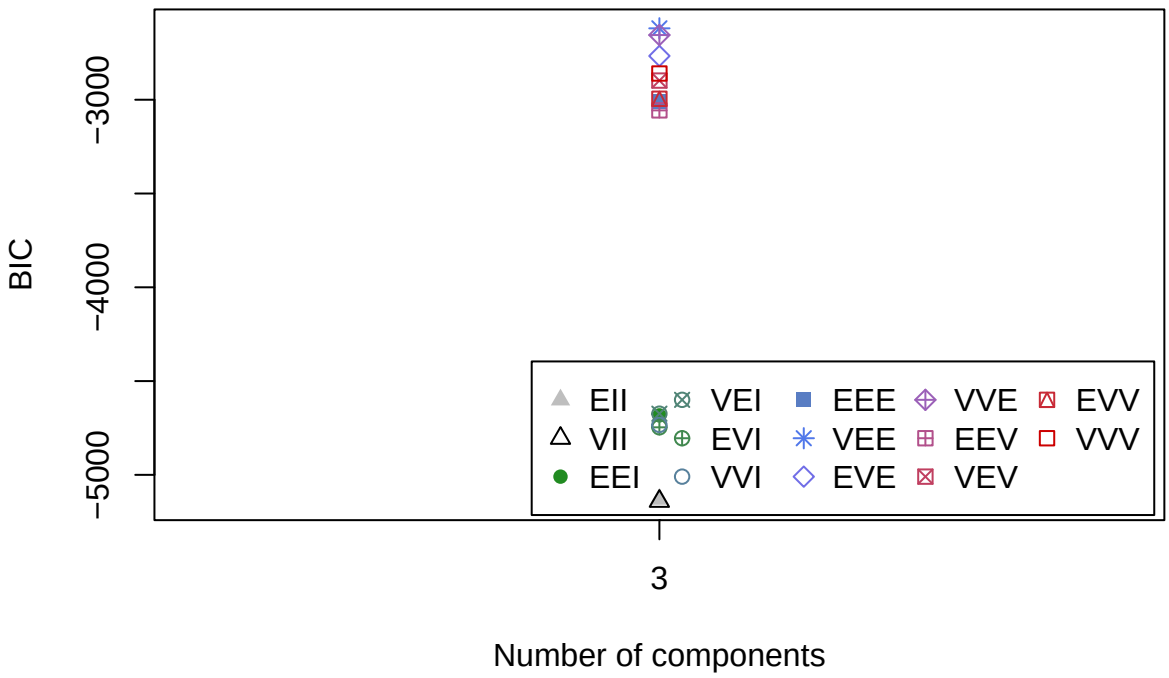


Observations with high uncertainty

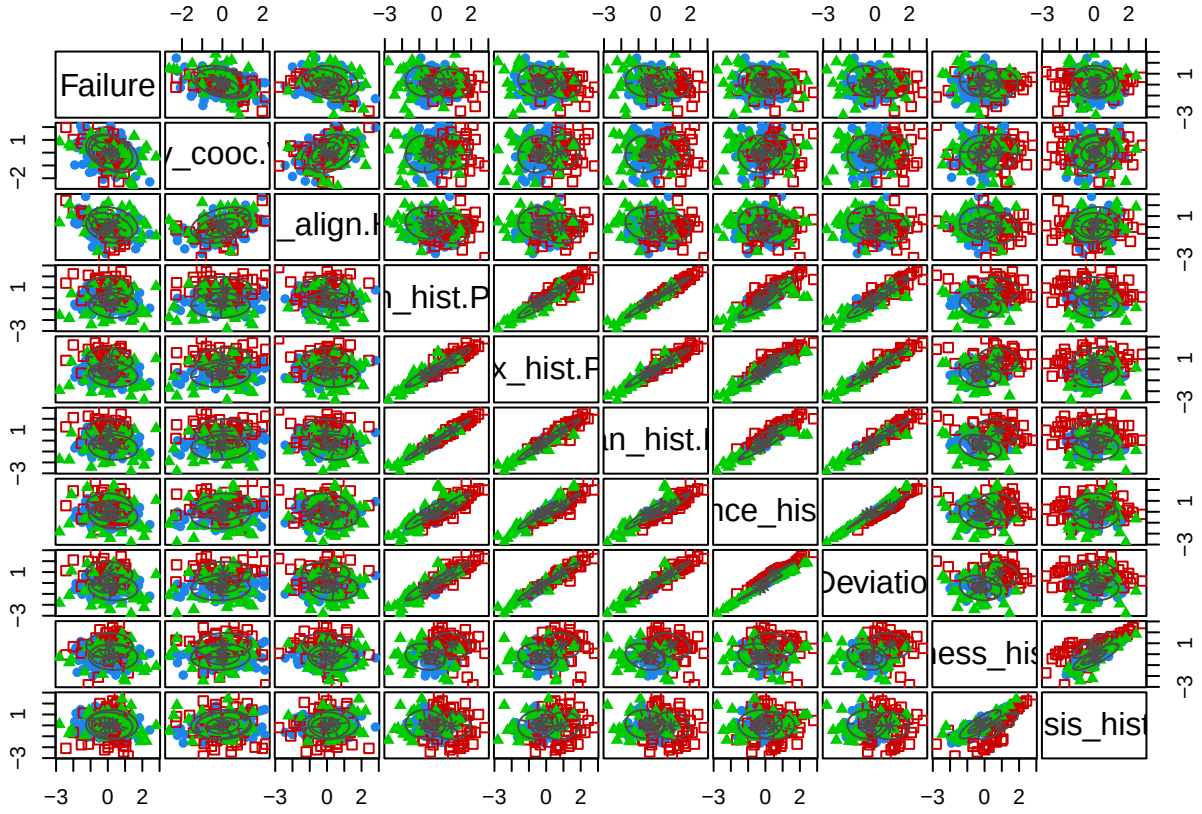
```
sort(model_based3$uncertainty, decreasing = TRUE) %>% head()
```

```
## [1] 0.4896053 0.4872327 0.4812039 0.4638017 0.4255382 0.3886809
```

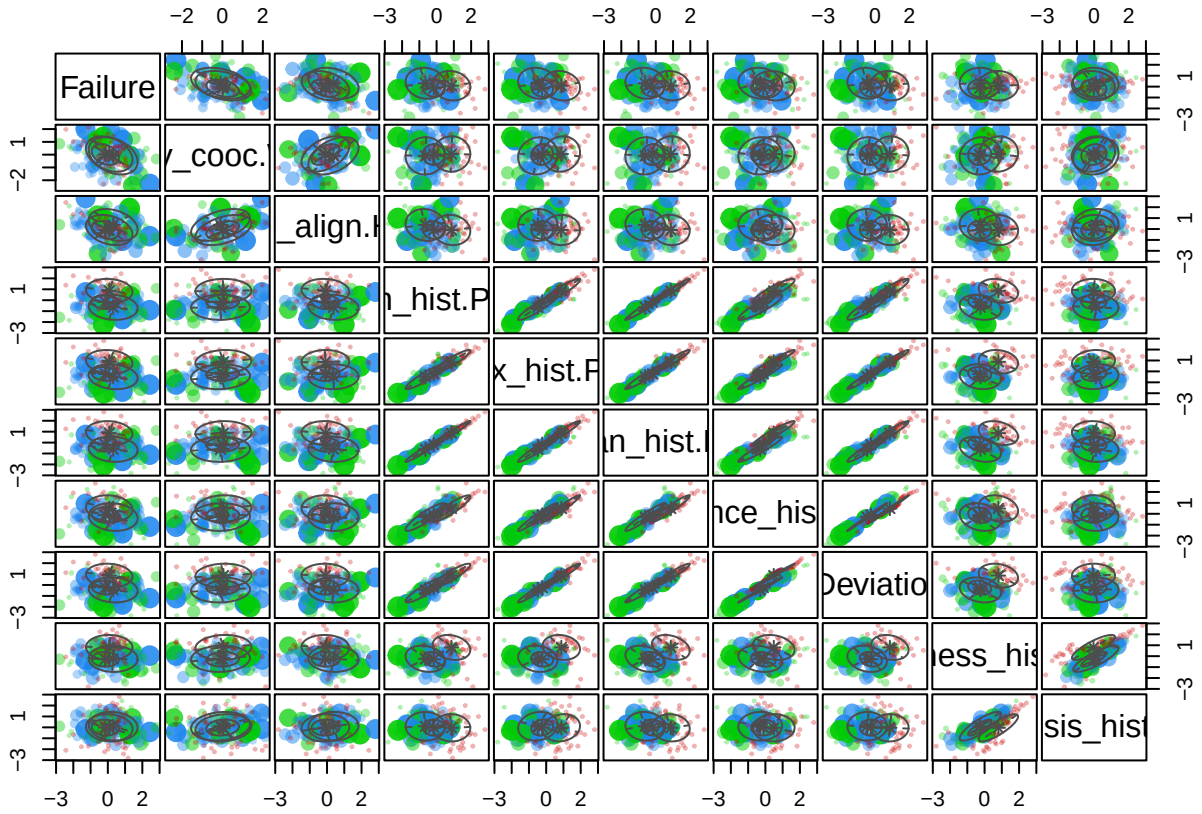
```
legend_args <- list(x = "bottomright", ncol = 5)
plot(model_based3, what = 'BIC', legendArgs = legend_args)
```




```
plot(model_based3, what = 'classification')
```




```
plot(model_based3, what = 'uncertainty')
```



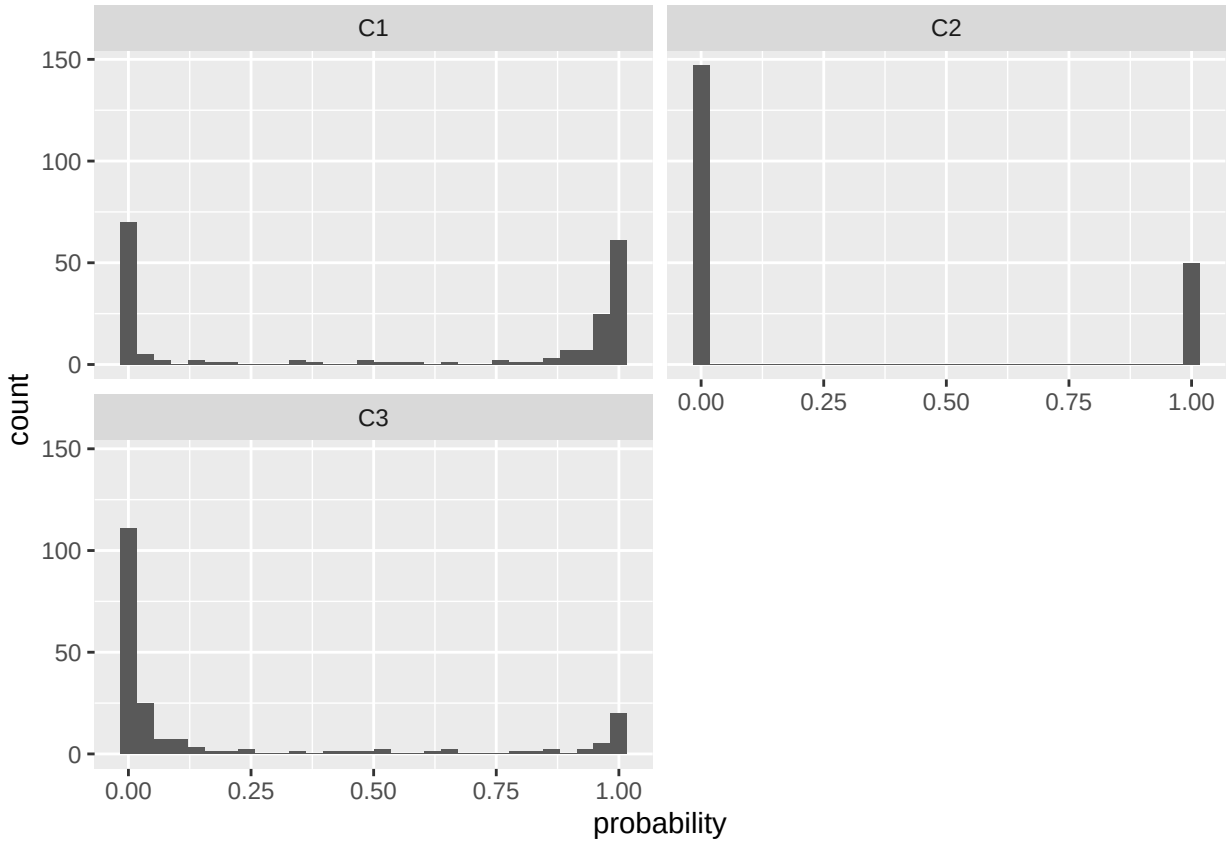

```
probabilities <- model_based3$z
colnames(probabilities) <- paste0('C', 1:3)
```

```
probabilities <- probabilities %>%
  as.data.frame() %>%
  mutate(id = row_number()) %>%
  tidyr::gather(cluster, probability, -id)
```

Plot the observations that are aligned to each cluster but their uncertainty of membership is greater than 0.25.

```
ggplot(probabilities, aes(probability)) +
  geom_histogram() +
  facet_wrap(~ cluster, nrow = 2)
```

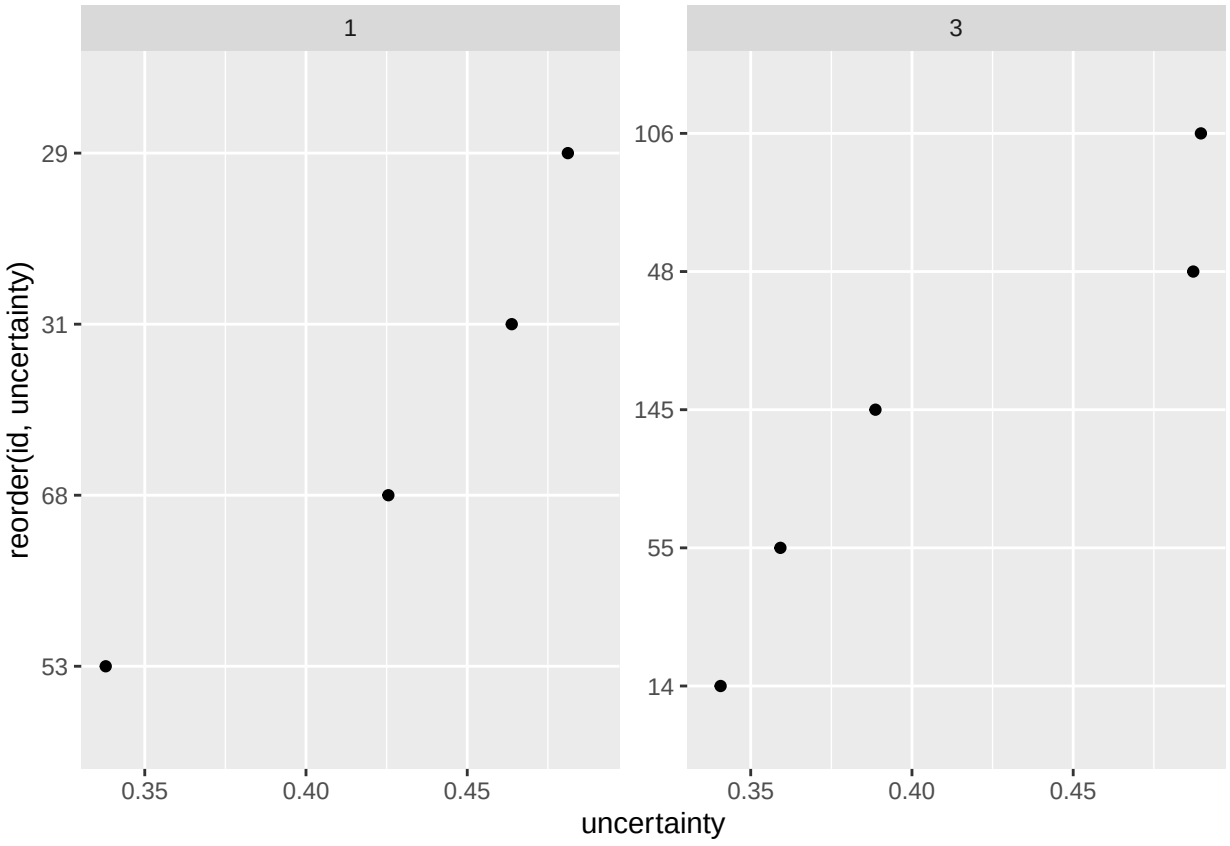
```
## `stat_bin()` using `bins = 30`. Pick better value with `binwidth`.
```




```
uncertainty <- data.frame(
  id = 1:nrow(radiomics_data),
  cluster = model_based3$classification,
  uncertainty = model_based3$uncertainty
)
```

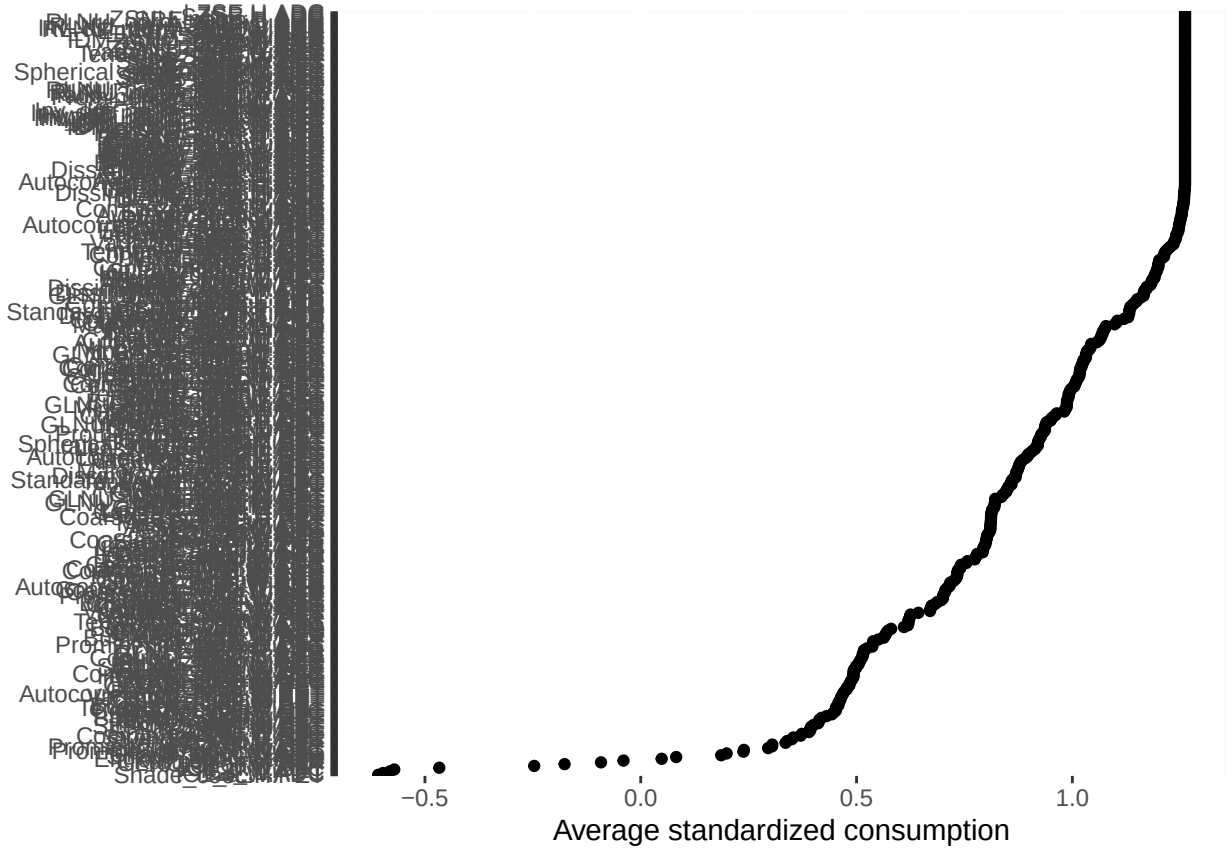
Plot the average standardized consumption for cluster 2 observations compared to all observations.

```
uncertainty %>%
  group_by(cluster) %>%
  filter(uncertainty > 0.25) %>%
  ggplot(aes(uncertainty, reorder(id, uncertainty))) +
  geom_point() +
  facet_wrap(~ cluster, scales = 'free_y', nrow = 1)
```




```
cluster2 <- radiomics_data %>%
  scale() %>%
  as.data.frame() %>%
  mutate(cluster = model_based3$classification) %>%
  filter(cluster == 2) %>%
  select(-cluster)
```

```
cluster2 %>%
  tidyr::gather(product, std_count) %>%
  group_by(product) %>%
  summarize(avg = mean(std_count)) %>%
  ggplot(aes(avg, reorder(product, avg))) +
  geom_point() +
  labs(x = "Average standardized consumption", y = NULL)
```



The advantage of model-based clustering over K-means and hierarchical clustering is that it automatically determines the ideal number of clusters. In this clustering, Gaussian mixture models is applied, which are one of the most popular model-based clustering approaches available. Using df values in k-means clustering since it is already standardized, we can use Mclust() function. Leaving G = NULL forces Mclust() to evaluate 1–9 clusters and select the optimal number of components based on BIC.