

# MODEL 3

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## Helper Packages And Modeling Packages

```
library(dplyr)

## Warning: package 'dplyr' was built under R version 4.1.3

##
## 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)

## Warning: package 'ggplot2' was built under R version 4.1.3

library(stringr)

## Warning: package 'stringr' was built under R version 4.1.3

library(cluster)
library(factoextra)

## Warning: package 'factoextra' was built under R version 4.1.3

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

library(gridExtra)

## Warning: package 'gridExtra' was built under R version 4.1.3
```

```

## 
## Attaching package: 'gridExtra'

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

library(tidyverse)

## Warning: package 'tidyverse' was built under R version 4.1.3

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

## v tibble  3.1.8      v purrr   0.3.4
## v tidyr   1.2.0      vforcats 0.5.2
## v readr   2.1.2

## Warning: package 'tibble' was built under R version 4.1.3

## Warning: package 'tidyr' was built under R version 4.1.3

## Warning: package 'readr' was built under R version 4.1.3

## Warning: package 'purrr' was built under R version 4.1.3

## Warning: package 'forcats' was built under R version 4.1.3

## -- 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)

## Warning: package 'mclust' was built under R version 4.1.3

## 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

library(tidyverse)
library(bestNormalize)

## Warning: package 'bestNormalize' was built under R version 4.1.3

```

We use the normalize radiomics dataset here.

Radiomics data contains 197 rows and 431 columns

Failure.binary: binary property to predict

Load and view radiomics dataset

```
radiomics = read_csv("C:\\\\Users\\\\MSU-TCTO_OVCAA\\\\Documents\\\\normalRad.csv")
```

```
## 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.
```

```
View(radiomics)
```

To remove any missing value that might present in the data

```
df <- na.omit(radiomics)
```

We don't want our algorithms to depend to an arbitrary variable unit, we start by scaling/standardizing the data

```
df <- scale(radiomics[c(3:431)])
head(df)
```

```
##           Failure Entropy_cooc.W.ADC GLNU_align.H.PET Min_hist.PET Max_hist.PET
## [1,]  1.1542812      0.55290547    -0.4333655   -0.2706594   -0.25747509
## [2,] -0.5335831     -0.06486729    -1.0166957    0.6709820    0.40556015
## [3,]  2.2372022      0.45990825    0.1792170   -1.4150181   -1.56968040
## [4,] -0.1405364     1.14318298    1.9997211   -0.2181792    0.07647307
## [5,]  0.7872480      0.34499368    0.1533960   -1.0603294   -1.15426355
## [6,] -2.8042412     0.84917904    0.3917753   -1.5696804   -1.91367122
##           Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET
## [1,]    -0.1921714      0.05095448            -0.06370859
## [2,]     0.4900236      0.68701098            0.50442967
## [3,]    -1.5275205     -1.56968040            -1.48790984
## [4,]    -0.1533960      0.01273346            -0.08924999
## [5,]    -1.4505021     -1.91367122            -1.91367122
## [6,]    -1.7165060     -1.83980971            -1.83980971
##           Skewness_hist.PET Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET
```

```

## [1,] -0.1533960 -0.3105060 -0.19217136 -0.1533960
## [2,] 0.1405248 -0.2443353 -0.08924999 -0.7700043
## [3,] -1.3180073 -1.4505021 -0.20515797 -0.1405248
## [4,] 0.1792170 0.8586682 -0.46150957 0.2181792
## [5,] 1.1298434 1.4879098 0.01273346 -0.9546481
## [6,] -0.2838909 0.1020415 -0.17921704 0.2312375
## AUC_hist.PET H_suv.PET Volume.PET X3D_surface.PET ratio_3ds_vol.PET
## [1,] -0.5189411 0.05095448 -0.8586682 -0.8404111 -0.2443353
## [2,] -0.3508513 1.03826584 -1.4150181 -0.5631547 0.6394275
## [3,] -0.7032182 -1.28828023 -0.2181792 0.2838909 -0.2706594
## [4,] 0.5932479 -0.25747509 0.4194224 0.9749140 -0.8224296
## [5,] 0.5781359 -1.61482620 -0.1405248 -0.6394275 0.6238874
## [6,] -0.3780645 -1.41501808 -0.7872387 -0.4055602 0.1533960
## ratio_3ds_vol_norm.PET irregularity.PET tumor_length.PET
## [1,] -0.57813595 0.32389526 -0.33734333
## [2,] 0.39177534 0.49002356 -0.51894198
## [3,] 0.14052475 -0.02546898 -0.01273363
## [4,] 0.27065942 -1.34894519 0.68701181
## [5,] 0.37806448 0.33734270 -0.75299666
## [6,] 0.01273346 0.05095448 -0.21817968
## Compactness_v1.PET Compactness_v2.PET Spherical_disproportion.PET
## [1,] -0.3038327 -0.4972144 -0.57813595
## [2,] -0.6709825 -0.9152478 0.39177534
## [3,] -0.5482991 -0.7700052 0.14052475
## [4,] -0.5932484 -0.8224305 0.27065942
## [5,] -0.6551238 -0.8960704 0.37806448
## [6,] -0.5044301 -0.7196129 0.01273346
## Sphericity.PET Asphericity.PET Center_of_mass.PET Max_3D_diam.PET
## [1,] -0.1921714 -0.57813595 0.36442422 -0.6238874
## [2,] -0.8404111 0.39177534 -0.03820863 -0.7700043
## [3,] -0.6551233 0.14052475 -0.75299544 -0.2838909
## [4,] -0.7196121 0.27065942 0.47571828 0.3105060
## [5,] -0.8224296 0.37806448 -0.19217136 -0.8224296
## [6,] -0.5781359 0.01273346 -1.06032943 -0.5044297
## Major_axis_length.PET Minor_axis_length.PET Least_axis_length.PET
## [1,] -0.8404111 -0.8047097 -0.3780645
## [2,] -0.7872387 -0.6394275 -0.7529954
## [3,] -0.2574751 -0.4900236 -0.2971722
## [4,] 0.2971722 0.7872387 0.9546481
## [5,] -0.7700043 -1.1298434 -0.7362013
## [6,] -0.4757183 -0.4473933 -1.3489452
## Elongation.PET Flatness.PET Max_cooc.L.PET Average_cooc.L.PET
## [1,] -0.23123752 0.3238953 -0.35085134 -0.10204149
## [2,] -0.07647307 -0.1662927 0.03820863 -0.29717220
## [3,] -0.82242955 -0.3917753 -0.32389526 0.47571828
## [4,] 0.27065942 0.7196121 -0.15339601 -1.17939112
## [5,] -0.67098197 -0.2574751 -0.02546898 -1.31800728
## [6,] -0.29717220 -1.3180073 -0.27065942 -0.05095448
## Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET DVAR_cooc.L.PET
## [1,] 0.06370859 0.1020415 -0.11484968 -0.2971722
## [2,] 0.33734270 -0.7529954 0.46150957 0.6394275
## [3,] 0.11484968 0.3780645 -0.05095448 -0.2838909
## [4,] -1.83980971 -0.7700043 -1.34894519 -1.5275205
## [5,] -0.62388738 -1.2052851 -0.49002356 -0.3508513

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## [6,] -0.20515797 0.1148497 -0.14052475 -0.2706594
## DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET SENT_cooc.L.PET
## [1,] -0.1662927 -0.10204149 0.2181792 0.23123752
## [2,] 0.4055602 -0.29717220 0.1662927 0.05095448
## [3,] -0.1405248 0.47571828 0.2706594 0.46150957
## [4,] -1.3489452 -1.17939112 -1.3489452 -0.82242955
## [5,] -0.5044297 -1.31800728 -0.8224296 -0.89606941
## [6,] -0.2051580 -0.06370859 -0.1792170 -0.06370859
## ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## [1,] -2.838909e-01 -0.03820863 -0.11484968
## [2,] -1.020415e-01 0.63942746 0.46150957
## [3,] -3.780645e-01 -0.02546898 -0.05095448
## [4,] -7.647307e-02 -1.28828023 -1.34894519
## [5,] -6.436293e-17 -0.35085134 -0.49002356
## [6,] -3.508513e-01 -0.07647307 -0.14052475
## Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## [1,] -0.37806448 -0.33734270 -0.44739330
## [2,] -0.62388738 -0.75299544 -0.59324787
## [3,] -0.65512329 -0.44739330 -0.70321822
## [4,] 0.40556015 0.40556015 0.41942235
## [5,] 0.05095448 0.02546898 0.06370859
## [6,] -0.36442422 -0.28389090 -0.39177534
## IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## [1,] -0.32389526 -0.4194224 0.02546898
## [2,] -0.78723867 -0.5482987 -1.08292088
## [3,] -0.37806448 -0.6394275 0.06370859
## [4,] 0.36442422 0.4757183 0.39177534
## [5,] 0.05095448 0.1148497 -0.54829867
## [6,] -0.24433531 -0.3780645 -0.24433531
## Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## [1,] -1.273346e-02 0.2181792 0.35085134
## [2,] -1.405248e-01 0.1662927 -0.05095448
## [3,] 7.529954e-01 0.2706594 -1.45050212
## [4,] -1.179391e+00 -1.3489452 -0.21817922
## [5,] -1.415018e+00 -0.8224296 0.75299544
## [6,] -6.436293e-17 -0.1792170 -0.08924999
## Prominence_cooc.L.PET IC1_.L.PET IC2_.L.PET Coarseness_vdif_.L.PET
## [1,] 0.29717220 0.1148497 -0.03820863 -1.276768e-01
## [2,] 0.11484968 -0.1276767 0.07647307 -1.405249e-01
## [3,] 0.10204149 0.3373427 -0.24433531 -6.370871e-02
## [4,] -1.15426355 0.9546481 -0.77000435 -5.335627e-01
## [5,] -0.08924999 0.3780645 -0.36442422 -9.599724e-08
## [6,] -0.14052475 0.3105060 -0.23123752 -7.647318e-02
## Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## [1,] 0.10204149 -0.4900236 -0.03820863
## [2,] 0.70321822 -0.5631547 0.56315472
## [3,] 0.07647307 -0.8772156 -0.35085134
## [4,] -1.52752054 0.8960694 -0.99558794
## [5,] -0.11484968 -0.5482987 -0.08924999
## [6,] -0.08924999 -0.6394275 -0.36442422
## Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
## [1,] 0.23123752 -1.533960e-01 -0.3780645 -0.5044297
## [2,] 0.37806448 6.370859e-02 -0.6709820 -0.6084963
## [3,] 0.05095448 -6.436293e-17 -0.6870110 -0.5482987

```

```

## [4,]      -1.10607816   -6.238874e-01       0.3917753      1.1542636
## [5,]       0.80470972   -1.792170e-01      -0.4333655     -0.4615096
## [6,]       0.11484968   -2.312375e-01      -0.3644242     -0.5189411
##    RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## [1,]      -0.4473933   -0.12767671      0.05095448     -0.03820863
## [2,]      -0.7529954   0.03820863      0.10204149     -0.10204149
## [3,]      -0.3917753   0.02546898     -0.54829867      0.56315472
## [4,]       1.2596485   -0.65512329     -0.35085134     -1.12984341
## [5,]      -0.7700043   -0.11484968      0.51894110     -1.38122903
## [6,]      -0.3780645   -0.17921704     -0.33734270      0.08924999
##    LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## [1,]       0.06370859   -0.01273346      0.03820863     -0.07647307
## [2,]       0.10204149   -0.10204149      0.19217136     -0.23123752
## [3,]      -0.54829867   0.56315472     -0.60849632      0.57813595
## [4,]      -0.35085134   -1.12984341     -0.28389090     -1.10607816
## [5,]       0.54829867   -1.31800728      0.50442967     -1.41501808
## [6,]      -0.32389526   0.08924999     -0.35085134      0.01273346
##    GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## [1,]      -2.838909e-01      -0.1148497      0.06370859
## [2,]      -6.436293e-17      0.2051580      0.31050605
## [3,]      -4.900236e-01      0.1533960      0.40556015
## [4,]      -1.020415e-01      -0.7362013     -1.45050212
## [5,]       2.443353e-01      -0.1405248     -0.91524677
## [6,]      -3.508513e-01      -0.1921714     -0.11484968
##    RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET LGLZE.L.PET
## [1,]      -0.3238953      0.01273346   -0.5189411      0.1921714      0.02546898
## [2,]      -0.5482987      -0.87721561   0.2574751     -0.7032182      0.10204149
## [3,]      -0.5781359      0.27065942   0.5335625     -2.2371600     -0.49002356
## [4,]       0.4900236      -0.49002356   -0.9152468      0.4473933     -0.36442422
## [5,]      -0.4055602      -1.52752054   0.3508513     -1.5696804      0.54829867
## [6,]      -0.3373427      0.12767671   -0.2971722     -0.1405248     -0.37806448
##    HGLZE.L.PET SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET
## [1,]      -0.01273346   -0.02546898   -0.08924999   0.16629268      0.1148497
## [2,]      -0.12767671   0.10204149   -0.10204149   0.12767671     -0.5044297
## [3,]       0.54829867   -0.40556015   0.59324787   -0.75299544      0.2574751
## [4,]      -1.12984341   -0.36442422   -1.06032943   -0.03820863     -0.8224296
## [5,]      -1.38122903   0.62388738   -1.23201233   0.27065942     -1.7747932
## [6,]       0.08924999   -0.39177534   0.02546898   -0.20515797      0.1405248
##    GLNU_area.L.PET ZSNU.L.PET ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET
## [1,]      -0.5189411   -0.5189411   -0.5044297     -0.29717220     -0.6084963
## [2,]      -0.6551233   -0.7872387   0.2051580     -0.01273346      0.3238953
## [3,]      -0.5335625   -0.3508513   0.5932479     -0.50442967      0.6084963
## [4,]       1.1542636   1.2052851   -1.0382658     -0.07647307     -1.1298434
## [5,]      -0.4333655   -0.7529954   0.4194224     0.25747509      0.4615096
## [6,]      -0.5044297   -0.4473933   -0.2706594     -0.35085134     -0.3238953
##    GLVAR_area.L.PET ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET
## [1,]       0.06370859   0.2312375      0.16629268     -0.6238874
## [2,]       0.27065942   -0.2312375     -0.93476628     -0.3373427
## [3,]       0.40556015   -1.6148262     -0.32389526      0.8404111
## [4,]      -1.45050212   0.9152468      0.23123752     -0.3780645
## [5,]      -0.91524677   -1.3180073     -1.71650601      1.9997211
## [6,]      -0.24433531   -0.1921714     -0.05095448      1.2596485
##    Average_cooc.H.PET Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET
## [1,]      -0.2971722     -4.333655e-01     -0.47571828     -0.3105060

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## [2,] -0.4900236 -3.917753e-01 0.08924999 0.2838909
## [3,] 0.3373427 -6.709820e-01 -1.45050212 -0.7700043
## [4,] -0.8772156 -6.436293e-17 -0.50442967 -0.4473933
## [5,] 0.6394275 -2.428639e+00 -1.99972110 -2.1037376
## [6,] 0.4194224 -1.205285e+00 -1.91367122 -1.2596485
## DVAR_cooc.H.PET DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET
## [1,] -0.4900236 0.28389090 -0.05095448 0.1148497
## [2,] -0.1020415 -0.95464809 -1.15426355 -0.5482987
## [3,] -0.1792170 0.16629268 0.49002356 0.4757183
## [4,] -0.5189411 0.03820863 -0.73620133 0.3238953
## [5,] -2.4286392 -0.08924999 0.65512329 0.1020415
## [6,] -0.3780645 -1.77479325 0.56315472 -1.2596485
## SENT_cooc.H.PET ASM_cooc.H.PET Contrast_cooc.H.PET
## [1,] 0.2574751 -0.4900236 -0.2838909
## [2,] 0.5044297 -0.6551233 0.2838909
## [3,] -0.6394275 0.9152468 -0.5631547
## [4,] 0.1662927 -0.4333655 -0.5335625
## [5,] -1.0603294 2.1037376 -2.4286392
## [6,] -0.9347663 1.3489452 -0.9749140
## Dissimilarity_cooc.H.PET Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET
## [1,] -0.3105060 -0.4757183 -0.28389090
## [2,] 0.2838909 -1.0166957 -0.63942746
## [3,] -0.7700043 0.5335625 0.10204149
## [4,] -0.4473933 -0.2574751 -0.08924999
## [5,] -2.1037376 1.0382658 0.62388738
## [6,] -1.2596485 0.9347663 0.40556015
## IDM_cooc.H.PET IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET
## [1,] -0.4900236 -0.23123752 0.1792170
## [2,] -1.0603294 -0.60849632 0.2706594
## [3,] 0.7700043 -0.10204149 -0.5781359
## [4,] -0.2574751 -0.06370859 0.2838909
## [5,] 1.1793911 0.60849632 -0.2838909
## [6,] 1.0166957 0.16629268 -0.6238874
## Correlation_cooc.H.PET Autocorrelation_cooc.H.PET Tendency_cooc.H.PET
## [1,] 0.01273346 -0.3508513 -0.2574751
## [2,] -0.84041109 -0.5932479 -0.4473933
## [3,] -0.12767671 0.3508513 -0.6870110
## [4,] 0.40556015 -0.7032182 0.2971722
## [5,] -0.99558794 0.6394275 -2.4286392
## [6,] -0.54829867 0.4333655 -1.1298434
## Shade_cooc.H.PET Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET
## [1,] 0.56315472 -0.2706594 0.36442422 -0.08924999
## [2,] -0.03820863 -0.3917753 0.89606941 -0.73620133
## [3,] -0.24433531 -0.6709820 -0.19217136 -0.31050605
## [4,] -0.59324787 0.5044297 -0.27065942 0.33734270
## [5,] 1.83980971 -2.4286392 0.32389526 -1.23201233
## [6,] 0.53356248 -1.2882802 -0.03820863 -0.75299544
## Coarseness_vdif.H.PET Contrast_vdif.H.PET Busyness_vdif.H.PET
## [1,] -0.11484971 -0.3780645 -0.6084963
## [2,] -0.03820861 -0.9749140 -0.8960694
## [3,] -0.29717235 1.2320123 -0.2706594
## [4,] -0.49002384 -0.5781359 0.6709820
## [5,] -0.19217145 -0.8772156 -0.6870110
## [6,] -0.36442443 1.4879098 -0.1020415

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##      Complexity_vdif.H.PET Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET
## [1,] -6.436293e-17      0.1533960      0.03820863     -0.5335625
## [2,]  2.971722e-01      0.4473933      0.49002356     -1.4505021
## [3,] -1.276767e-01      0.3238953     -1.20528514      0.6238874
## [4,] -2.443353e-01     -0.8224296     -0.35085134     -0.1020415
## [5,] -8.224296e-01      1.0166957     -1.56968040      0.8047097
## [6,] -2.706594e-01      0.3105060     -1.71650601      1.1542636
##      RLNU_align.H.PET RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET
## [1,] -0.3238953      0.01273346     -0.24433531     -0.4757183
## [2,] -0.5044297      0.49002356     -0.21817922     -0.7872387
## [3,] -0.7032182     -1.34894519     -0.32389526      0.1276767
## [4,]  0.9347663     -0.44739330     -0.02546898     -0.4194224
## [5,] -1.0603294     -1.61482620     -0.49002356      0.6394275
## [6,] -0.8960694     -1.83980971     -0.43336550      0.5482987
##      LGSRE_align.H.PET HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET
## [1,] -0.21817922    -0.32389526     -0.23123748     -0.5932479
## [2,] -0.19217136    -0.05095448     -0.28389089     -1.7747932
## [3,] -0.33734270    -1.41501808     -0.33734273      0.9955879
## [4,] -0.06370859    -0.67098197      0.03820884     -0.1921714
## [5,] -0.49002356    0.63942746     -0.44739340      1.2596485
## [6,] -0.46150957    0.10204149     -0.32389528      1.3812290
##      GLNU_norm_align.H.PET RLNU_norm_align.H.PET GLVAR_align.H.PET
## [1,] -0.3917753     -6.436293e-17     -0.4194224
## [2,] -0.6394275      5.335625e-01     -0.5335625
## [3,]  0.7362013     -1.318007e+00     -0.7032182
## [4,] -0.4900236     -4.473933e-01     0.1405248
## [5,]  1.4505021     -1.569680e+00     -2.4286392
## [6,]  1.1060782     -1.839810e+00     -1.2052851
##      RLVAR_align.H.PET Entropy_align.H.PET SZSE.H.PET LZSE.H.PET LGLZE.H.PET
## [1,] -0.4900236     -0.2706594     -0.2706594     -0.1405248     -0.23123752
## [2,] -1.2596485     -0.1020415     0.7196121     -2.8041692     -0.21817922
## [3,]  1.0603294     -1.1298434     -0.9955879     0.9152468     -0.32389526
## [4,]  0.1020415     0.1662927     -0.4900236     0.8224296     -0.07647307
## [5,]  1.1793911     -1.7165060     -1.2052851     1.1298434     -0.49002356
## [6,]  1.4505021     -1.1542636     -1.2320123     1.4879098     -0.40556015
##      HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET LZLGE.H.PET LZHGE.H.PET
## [1,]  1.276767e-01   -0.2181792     -0.02546898     -0.37806448     -0.2838909
## [2,] -6.551233e-01   -0.1662927     0.36442422     -0.70321822     -1.9997211
## [3,] -6.436293e-17   -0.3373427     -1.31800728     0.01273346      0.9347663
## [4,]  5.932479e-01   -0.1276767     -0.62388738     0.70321822     0.5932479
## [5,]  6.870110e-01   -0.4900236     0.46150957     0.54829867     1.0166957
## [6,]  3.917753e-01   -0.4333655     -0.95464809     1.17939112     1.4150181
##      GLNU_area.H.PET ZSNU.H.PET ZSP.H.PET GLNU_norm.H.PET ZSNU_norm.H.PET
## [1,] -0.4615096     -0.32389526     -0.1662927     -0.3917753     -0.2181792
## [2,] -0.5932479     -0.01273346     0.8960694     -0.6551233     0.8586682
## [3,] -0.2312375     -0.82242955     -0.9749140     0.8960694     -1.0603294
## [4,]  1.1298434     0.77000435     -0.6084963     -0.4615096     -0.4757183
## [5,] -0.6084963     -1.17939112     -1.1298434     0.9955879     -1.2320123
## [6,] -0.4757183     -1.12984341     -1.2882802     1.0382658     -1.3812290
##      GLVAR_area.H.PET ZSVAR_H.PET Entropy_area.H.PET Max_cooc.W.PET
## [1,] -0.4333655     -0.2181792     -0.2838909     -0.4757183
## [2,] -0.4900236     -1.8398097     -0.8224296     -0.3780645
## [3,] -0.8224296     0.8224296     -0.9546481     0.4473933
## [4,]  0.1792170     0.7529954     0.6084963     -0.4333655

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## [5,]      -2.4286392  0.9749140      -1.1060782  1.5275205
## [6,]      -0.9546481  1.3489452      -1.0382658  0.9152468
## Average_cooc.W.PET Variance_cooc.W.PET Entropy_cooc.W.PET DAVE_cooc.W.PET
## [1,]      -0.11484968  0.02546898     -0.1020415  -0.1020415
## [2,]       0.27065942  0.70321822     0.1662927  0.5631547
## [3,]      -1.15426355  -1.56968040    -1.1793911  -1.4879098
## [4,]      -0.02546898  -0.01273346    -0.1148497  -0.2838909
## [5,]      -2.42863924  -1.83980971    -1.9136712  -1.7165060
## [6,]      -1.83980971  -1.91367122    -1.8398097  -1.7747932
## DVAR_cooc.W.PET DENT_cooc.W.PET SAVE_cooc.W.PET SVAR_cooc.W.PET
## [1,]      0.01273346  -0.1921714   -0.11484968  0.05095448
## [2,]       0.78723867  0.2971722   0.27065942  0.67098197
## [3,]      -1.48790984  -1.4150181   -1.15426355  -1.45050212
## [4,]      -0.10204149  -0.3508513   -0.02546898  0.02546898
## [5,]      -1.31800728  -1.6148262   -2.42863924  -1.83980971
## [6,]      -1.77479325  -1.7747932   -1.83980971  -1.91367122
## SENT_cooc.W.PET ASM_cooc.W.PET Contrast_cooc.W.PET
## [1,]      0.01273346  -0.3508516   0.01273346
## [2,]       0.37806448  -0.4403688   0.80470972
## [3,]      -1.28828023  0.4757183   -1.45050212
## [4,]       0.05095448  -0.3238955   -0.15339601
## [5,]      -1.83980971  1.4505024   -1.56968040
## [6,]      -1.71650601  1.0166959   -1.77479325
## Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET Inv_diff_norm_cooc.W.PET
## [1,]           -0.1020415  -0.4757183   -0.28389090
## [2,]        0.5631547  -1.0382658   -0.85866816
## [3,]        -1.4879098  0.4900236   -0.23123752
## [4,]        -0.2838909  -0.2706594   0.37806448
## [5,]        -1.7165060  0.7529954   0.11484968
## [6,]        -1.7747932  0.7032182   -0.07647307
## IDM_cooc.W.PET IDM_norm_cooc.W.PET Inv_var_cooc.W.PET
## [1,]      -0.4757183  -0.27726923  -0.4333655
## [2,]      -1.0382658  -0.78723892  -0.9749140
## [3,]       0.7196121  -0.20515808  0.7700043
## [4,]      -0.2706594  0.36442425  -0.2181792
## [5,]       0.9749140  0.05095443  0.8047097
## [6,]       0.9546481  -0.03820870  0.9955879
## Correlation_cooc.W.PET Autocorrelation_cooc.W.PET Tendency_cooc.W.PET
## [1,]      0.02546898  0.05095448  0.05095448
## [2,]      -1.06032943  0.35085134  0.67098197
## [3,]       0.06370859  -1.12984341  -1.45050212
## [4,]       0.37806448  0.11484968  0.02546898
## [5,]      -0.73620133  -2.23715996  -1.83980971
## [6,]      -0.28389090  -1.83980971  -1.91367122
## Shade_cooc.W.PET Prominence_cooc.W.PET IC1_d.W.PET IC2_d.W.PET
## [1,]       0.2838909  0.03820863  3.780645e-01 -0.11484968
## [2,]       0.5335625  0.67098197  2.574751e-01  0.02546898
## [3,]      -1.5696804  -1.45050212 -6.436293e-17 -0.41942235
## [4,]       0.3917753  0.23123752 -1.020415e-01  0.17921704
## [5,]      -0.6551233  -1.41501808  6.709820e-01 -1.45050212
## [6,]      -1.2052851  -1.83980971  1.921714e-01 -0.95464809
## Coarseness_vdif.W.PET Contrast_vdif.W.PET Busyness_vdif.W.PET
## [1,]      -1.533960e-01  0.08924999  -0.43336550
## [2,]      -1.405248e-01  1.06032943  -1.06032943

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## [3,]      -6.436293e-17      -1.03826584      0.54829867
## [4,]      -5.482987e-01      -0.80470972      0.07647307
## [5,]      2.546898e-02      -1.41501808      0.80470972
## [6,]      -7.647307e-02      -1.38122903      1.01669574
## Complexity_vdif.W.PET Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET
## [1,]      -0.1020415       0.3917753       0.1148497      -0.5189411
## [2,]      0.5631547       1.0166957       0.4055602      -1.2882802
## [3,]      -1.2320123       -1.4505021      -0.9749140      0.3644242
## [4,]      0.1792170       -0.4194224      -0.2838909      -0.1533960
## [5,]      -1.2052851       -0.6551233      -1.2596485      0.4194224
## [6,]      -1.8398097       -1.6148262      -1.5275205      0.5482987
## GLNU_align.W.PET RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET
## [1,]      -0.77000435     -0.3238953       0.07647307     -0.1405248
## [2,]      -1.23201233     -0.6394275       0.41942235     -0.2971722
## [3,]      -0.11484968     -0.5932479      -1.12984341     0.5482987
## [4,]      1.08292088      1.2052851       -0.32389526     -0.7529954
## [5,]      -0.03820863     -0.9749140      -1.34894519     1.3812290
## [6,]      0.10204149      -0.6551233      -1.56968040     0.8960694
## HGRE_align.W.PET LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET
## [1,]      -6.436293e-17     -0.1276767      -6.436293e-17     -0.1405248
## [2,]      3.780645e-01      -0.2971722      3.780645e-01      -0.3644242
## [3,]      -1.232012e+00     0.4900236       -1.205285e+00     0.6238874
## [4,]      1.662927e-01      -0.7529954      1.148497e-01      -0.6709820
## [5,]      -2.428639e+00     1.2596485       -1.913671e+00     1.6148262
## [6,]      -1.839810e+00     0.8586682       -1.839810e+00     1.0829209
## HGLRE_align.W.PET GLNU_norm_align.W.PET RLNU_norm_align.W.PET
## [1,]      -0.1276767       -0.3780645       0.05095448
## [2,]      0.3238953       -0.6084963       0.49002356
## [3,]      -1.0603294       0.5932479       -1.15426355
## [4,]      0.1792170       -0.5044297       -0.37806448
## [5,]      -2.4286392       1.4879098       -1.52752054
## [6,]      -1.8398097       1.1060782       -1.66352051
## GLVAR_align.W.PET RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET
## [1,]      0.03820863     -0.43336555     -0.24433531     -0.1020415
## [2,]      0.68701098     -0.99558812     -0.03820863     0.6084963
## [3,]      -1.56968040     0.93476655     -1.12984341     -0.9347663
## [4,]      0.02546898     -0.02546894     0.06370859     -0.4900236
## [5,]      -1.91367122     0.99558823     -2.23715996     -1.2052851
## [6,]      -1.83980971     1.25964883     -1.25964848     -1.3180073
## LZSE.W.PET LGLZE.W.PET HGLZE.W.PET SZLGE.W.PET SHGGE.W.PET LZLGE.W.PET
## [1,]      -0.4473933     -0.2443353     -6.436293e-17    -0.2574751     0.01273346    -0.01273346
## [2,]      -1.4879098     -0.3373427     3.917753e-01    -0.2051580     0.46150957    -0.53356248
## [3,]      0.6709820      0.7700043     -1.232012e+00   0.8047097     -1.31800728   0.54829867
## [4,]      0.2051580      -0.7032182     1.148497e-01    -0.7872387     0.11484968    -0.27065942
## [5,]      0.7700043      1.3489452     -1.913671e+00   1.2052851     -1.83980971   1.20528514
## [6,]      1.2882802      0.9152468     -1.839810e+00   0.9546481     -1.91367122   1.61482620
## LZHGE.W.PET GLNU_area.W.PET ZSNU.W.PET ZSP.W.PET GLNU_norm.W.PET
## [1,]      -0.4194224     -0.5781359     -0.2312375     -0.2181792     -0.4055602
## [2,]      -0.2181792     -1.0382658     -0.3238953     0.5932479     -0.5932479
## [3,]      -0.6394275     -0.1148497     -0.6870110     -1.0382658     0.7362013
## [4,]      0.4333655      1.1060782     0.8960694     -0.5932479     -0.5189411
## [5,]      -2.1037376     -0.2574751     -1.1793911     -1.1542636     1.3489452
## [6,]      -0.8960694     -0.1533960     -0.9749140     -1.4879098     1.1793911
## ZSNU_norm.W.PET GLVAR_area.W.PET ZSVAR.W.PET Entropy_area.W.PET

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## [1,] -0.2051580 0.03820863 -0.3373427 -0.3508513
## [2,] 0.6870110 0.62388738 -1.0166957 -0.4473933
## [3,] -0.9749140 -1.28828023 0.8224296 -1.1542636
## [4,] -0.5335625 0.06370859 0.4055602 0.3780645
## [5,] -1.3180073 -1.77479325 0.8047097 -1.5696804
## [6,] -1.4505021 -1.83980971 1.2882802 -1.0166957
## Min_hist.ADC Max_hist.ADC Mean_hist.ADC Variance_hist.ADC
## [1,] 0.4475228 -0.31070344 -0.05095448 0.4333655
## [2,] -1.1111899 -0.42661942 -0.31050605 -0.2181792
## [3,] 0.6402049 0.50450261 0.06370859 1.1060782
## [4,] -1.1111899 0.51901885 -0.11484968 0.7032182
## [5,] -1.1111899 -0.06382412 -1.01669574 0.3644242
## [6,] -1.1111899 0.08918521 0.46150957 1.7747932
## Standard_Deviation_hist.ADC Skewness_hist.ADC Kurtosis_hist.ADC
## [1,] 0.2443353 0.9546481 -0.2181792
## [2,] -0.3917753 -1.5696804 0.7362013
## [3,] 0.7362013 1.4150181 1.2320123
## [4,] 0.4333655 -0.4333655 -0.4757183
## [5,] 0.1533960 -0.3105060 -0.1792170
## [6,] 1.1542636 -1.0829209 -2.8041692
## Energy_hist.ADC Entropy_hist.ADC AUC_hist.ADC Volume.ADC X3D_surface.ADC
## [1,] 0.15339594 -1.61482620 -0.2181796 -0.8404111 -1.3180073
## [2,] -0.07647335 -0.82242955 -0.9546489 -1.2320123 -0.9546481
## [3,] -0.25090024 -0.01273346 0.3780644 -0.2706594 -0.4757183
## [4,] -0.41942296 0.41942235 -0.2443357 0.3917753 0.2574751
## [5,] -0.18569070 -0.20515797 -0.5482992 -0.2181792 -0.4615096
## [6,] -0.28389138 -0.02546898 -1.0166966 -0.7362013 -0.3373427
## ratio_3ds_vol.ADC ratio_3ds_vol_norm.ADC irregularity.ADC
## [1,] 0.7700047 -0.02546898 0.43336550
## [2,] 0.1533962 -1.10607816 -0.03820863
## [3,] -0.4757183 -1.52752054 -1.34894519
## [4,] -0.5044297 0.29717220 -0.84041109
## [5,] -0.3780645 -1.15426355 -0.99558794
## [6,] 0.3105063 0.41942235 -0.27065942
## Compactness_v1.ADC Compactness_v2.ADC Spherical_disproportion.ADC
## [1,] -0.24433531 -0.5044297 -0.02546898
## [2,] 0.03820863 0.4194224 -1.10607816
## [3,] 0.12767671 0.6084963 -1.52752054
## [4,] -0.44739330 -1.0829209 0.29717220
## [5,] 0.05095448 0.4757183 -1.15426355
## [6,] -0.53356248 -1.3812290 0.41942235
## Sphericity.ADC Asphericity.ADC Center_of_mass.ADC Max_3D_diam.ADC
## [1,] -0.4900236 -0.02546898 0.2574751 -1.38122903
## [2,] 0.3780645 -1.10607816 0.2971722 -0.77000435
## [3,] 0.5044297 -1.52752054 0.7032182 -0.59324787
## [4,] -1.1298434 0.31050605 0.5781359 0.07647307
## [5,] 0.4194224 -1.15426355 -0.4055602 -0.68701098
## [6,] -1.4150181 0.50442967 0.7362013 -0.50442967
## Major_axis_length.ADC Minor_axis_length.ADC Least_axis_length.ADC
## [1,] -0.50442967 -1.52752054 -1.48790984
## [2,] -1.38122903 -0.75299544 -0.39177534
## [3,] -0.97491405 -0.31050605 -0.21817922
## [4,] -0.02546898 -0.01273346 0.19217136
## [5,] -1.06032943 -0.36442422 0.01273346

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## [6,] -0.24433531 -0.37806448 -0.53356248
## Elongation.ADC Flatness.ADC Max_cooc.L.ADC Average_cooc.L.ADC
## [1,] -2.42863924 -2.4286397 0.10204149 -0.7196121
## [2,] 0.01273346 0.4194225 -0.29717220 0.4055602
## [3,] 0.28389090 0.1792171 -0.01273346 -2.4286392
## [4,] -0.39177534 0.1084434 -0.08924999 -0.4055602
## [5,] 0.46150957 0.7032184 -0.12767671 -0.3105060
## [6,] -0.67098197 -0.9749142 -0.49002356 0.3373427
## Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC DVAR_cooc.L.ADC
## [1,] 0.7872387 -0.87721561 0.36442422 1.3180073
## [2,] -0.5932479 -0.57813595 -0.51894110 -0.6238874
## [3,] 1.0166957 -0.08924999 0.07647307 1.1298434
## [4,] -0.7700043 -0.60849632 -1.08292088 -1.1542636
## [5,] -0.4194224 -0.25747509 -0.31050605 -0.4900236
## [6,] 1.2052851 0.60849632 0.29717220 0.8586682
## DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC SENT_cooc.L.ADC
## [1,] 0.43336550 -0.7196121 0.6709820 -0.2181792
## [2,] -0.51894110 0.4055602 -0.7529954 -1.3812290
## [3,] 0.07647307 -2.4286392 1.1793911 0.6394275
## [4,] -0.97491405 -0.4055602 -0.6394275 -0.1405248
## [5,] -0.33734270 -0.3105060 -0.6084963 -0.2312375
## [6,] 0.37806448 0.3373427 1.3812290 -0.9749140
## ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## [1,] 2.730047e-06 1.1060782 0.36442422
## [2,] -1.662910e-01 -0.5044297 -0.51894110
## [3,] -1.020394e-01 0.6870110 0.07647307
## [4,] -1.276748e-01 -1.1060782 -1.08292088
## [5,] -2.443342e-01 -0.3105060 -0.31050605
## [6,] -4.686025e-01 0.7872387 0.29717220
## Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## [1,] -0.2838909 -0.67098275 -1.921714e-01
## [2,] -0.2312375 -0.05095454 -2.574751e-01
## [3,] -0.1276767 -0.35085175 -6.436293e-17
## [4,] 0.2706594 0.31050641 2.838909e-01
## [5,] -0.3373427 -0.17921725 -3.373427e-01
## [6,] -0.7032182 -0.68701178 -6.709820e-01
## IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## [1,] -0.87721561 -2.443353e-01 -0.8586682
## [2,] -0.07647307 -2.051580e-01 -0.5781359
## [3,] -0.49002356 -6.436293e-17 0.4900236
## [4,] 0.19217136 2.443353e-01 0.4473933
## [5,] -0.16629268 -3.373427e-01 -0.6084963
## [6,] -0.62388738 -7.032182e-01 0.5932479
## Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC
## [1,] -0.7196121 0.6709820 1.4150181
## [2,] 0.5781359 -0.7529954 -1.1793911
## [3,] -1.9136712 1.1793911 2.2371600
## [4,] -0.3917753 -0.6394275 -0.3780645
## [5,] -0.2971722 -0.6084963 -0.4473933
## [6,] 0.6238874 1.3812290 -1.5696804
## Prominence_cooc.L.ADC IC1_.L.ADC IC2_.L.ADC Coarseness_vdif_.L.ADC
## [1,] 1.1298434 -0.93476628 0.50442967 0.47571994
## [2,] -0.6238874 0.60849632 -0.28389090 0.06370943
## [3,] 2.2371600 -0.07647307 0.20515797 -0.17921668

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## [4,] -0.9152468 0.16629268 -0.06370859 -0.31050595
## [5,] -0.6084963 0.70321822 -0.33734270 -0.05095386
## [6,] 1.1793911 -0.37806448 0.44739330 -0.07008883
## Contrast_vdif_.L.ADC Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC
## [1,] 1.1060782 -1.0603294 0.5631547
## [2,] -0.3105060 -0.9955879 -0.8586682
## [3,] 0.3373427 0.2443353 0.8586682
## [4,] -0.9546481 0.1662927 -1.0603294
## [5,] -0.1533960 -0.5044297 -0.6551233
## [6,] 0.8404111 -0.7700043 0.6870110
## Strength_vdif_.L.ADC SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC
## [1,] 1.3812290 0.01910130 -0.51894110 -1.3180073
## [2,] 0.6238874 -0.02546860 -0.43336550 -0.5932479
## [3,] 0.8404111 -0.31050614 -0.06370859 -0.2838909
## [4,] -0.7032182 -0.57813649 0.15339601 0.2706594
## [5,] 0.2838909 0.05095499 -0.49002356 -0.5189411
## [6,] 0.5932479 0.20515874 -0.87721561 -0.7872387
## RLNU_align.L.ADC RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC
## [1,] -1.5275205 0.05095448 -0.06370859 -0.3644242
## [2,] -0.7529954 -0.02546898 -0.39177534 0.4194224
## [3,] -0.2838909 -0.28389090 0.10204149 -1.9997211
## [4,] 0.2971722 -0.59324787 -0.12767671 -0.4757183
## [5,] -0.5781359 0.03820863 -0.23123752 -0.3508513
## [6,] -0.5189411 0.24433531 -0.40556015 0.6551233
## LGSRE_align.L.ADC HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC
## [1,] -0.06370884 -0.2574751 -0.10204149 -0.4900236
## [2,] -0.39177578 0.4194224 -0.40556015 0.4194224
## [3,] 0.07647290 -1.9997211 0.08924999 -1.9997211
## [4,] -0.14052504 -0.4757183 -0.08924999 -0.3780645
## [5,] -0.23123786 -0.3105060 -0.24433531 -0.3508513
## [6,] -0.40556060 0.6709820 -0.41942235 0.6238874
## GLNU_norm_align.L.ADC RLNU_norm_align.L.ADC GLVAR_align.L.ADC
## [1,] -0.11484968 0.05095457 0.8586682
## [2,] -0.08924999 -0.05095441 -0.5482987
## [3,] -0.21817922 -0.29717219 0.8960694
## [4,] -0.12767671 -0.67098206 -0.8047097
## [5,] -0.24433531 0.03820873 -0.3644242
## [6,] -0.75299544 0.29717236 1.0603294
## RLVAR_align.L.ADC Entropy_align.L.ADC SZSE.L.ADC LZSE.L.ADC LGLZE.L.ADC
## [1,] -0.43336634 -0.4194224 0.24433538 -0.87721561 -0.07647307
## [2,] -0.41942318 -0.8586682 -0.03820862 -0.59324787 -0.39177534
## [3,] -0.07647358 0.1921714 -0.89606958 0.23123752 0.11484968
## [4,] 0.21817897 -0.3644242 -0.51894119 -0.02546898 -0.19217136
## [5,] -0.36442500 -0.3780645 -0.29717224 -0.10204149 -0.20515797
## [6,] -0.78723983 0.6238874 0.20515804 -1.20528514 -0.40556015
## HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC LZLGE.L.ADC LZHGE.L.ADC
## [1,] -0.2838909 -0.06370838 -0.1662927 -0.14052487 -0.9955879
## [2,] 0.4194224 -0.37806447 0.3373427 -0.47571848 0.2971722
## [3,] -1.9997211 0.08925030 -1.9997211 0.50442973 -1.6635205
## [4,] -0.4900236 -0.25747501 -0.6551233 -0.06370868 -0.4333655
## [5,] -0.4473933 -0.19217124 -0.4473933 -0.27065957 -0.3917753
## [6,] 0.6238874 -0.40556016 0.6238874 -0.50442988 0.3780645
## GLNU_area.L.ADC ZSNU.L.ADC ZSP.L.ADC GLNU_norm.L.ADC ZSNU_norm.L.ADC
## [1,] -1.3180073 -1.4879098 0.25747509 -0.11484983 0.2971730

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## [2,] -0.5482987 -0.9546481  0.03820863   -0.08925014   -0.0764728
## [3,] -0.3917753 -0.4615096 -0.97491405   -0.32389548   -1.1793926
## [4,]  0.2971722  0.3508513 -0.51894110   -0.12767687   -0.6870117
## [5,] -0.5335625 -0.6394275 -0.33734270   -0.25747529   -0.3105061
## [6,] -0.7529954 -0.4900236  0.33734270   -0.71961240    0.2312383
##      GLVAR_area.L.ADC ZSVAR.L.ADC Entropy_area.L.ADC Max_cooc.H.ADC
## [1,]  0.8772156 -0.80470972   -0.7529954   -0.11484998
## [2,] -0.5631547 -0.63942746   -1.2882802   -0.27065984
## [3,]  0.8224296  0.44739330   0.5781359   0.07647291
## [4,] -0.8586682  0.06370859   -0.2051580   -0.12767702
## [5,] -0.3373427  0.01273346   -0.1276767   -0.39865881
## [6,]  1.0603294 -1.25964848   0.5932479   -0.07647334
##      Average_cooc.H.ADC Variance_cooc.H.ADC Entropy_cooc.H.ADC DAVE_cooc.H.ADC
## [1,] -1.2052851   -0.9546481   0.49002356  0.10204149
## [2,]  0.5781359   -0.8047097   -0.70321822  0.01273346
## [3,] -0.8047097   0.6394275   -0.23123752 -0.67098197
## [4,] -0.5631547   -0.9955879   0.12767671 -1.23201233
## [5,] -0.1792170   -1.7165060   -0.06370859 -0.03820863
## [6,] -0.8404111   0.5631547   -0.75299544 -1.20528514
##      DVAR_cooc.H.ADC DENT_cooc.H.ADC SAVE_cooc.H.ADC SVAR_cooc.H.ADC
## [1,]  0.07647307  0.01273556   -1.2052851   -0.8404111
## [2,] -0.36442422 -0.03820676   0.5781359   -0.4900236
## [3,] -0.35085134 -0.57813651   -0.7872387   0.3508513
## [4,] -1.28828023 -1.25965212   -0.5932479   0.1020415
## [5,] -0.23123752 -0.02546706   -0.1792170   -0.8224296
## [6,] -0.80470972 -1.12984646   -0.8404111   0.4615096
##      SENT_cooc.H.ADC ASM_cooc.H.ADC Contrast_cooc.H.ADC
## [1,]  0.2838909  0.02548452   0.06370859
## [2,] -1.7165060 -0.20515786   -0.05095448
## [3,]  0.1405248 -0.08285155   -0.62388738
## [4,] -0.1662927 -0.29717824   -1.31800728
## [5,] -0.5631547 -0.25090274   -0.06370859
## [6,] -0.6870110 -0.05094405   -1.10607816
##      Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC Inv_diff_norm_cooc.H.ADC
## [1,]          0.10204149   -0.3780651   -0.50442967
## [2,]          0.01273346   -0.6238881   -0.40556015
## [3,]          -0.67098197   0.1792168   0.01273346
## [4,]          -1.23201233   0.2574749   0.28389090
## [5,]          -0.03820863   -0.2838914   -0.32389526
## [6,]          -1.20528514   0.3917753   0.31050605
##      IDM_cooc.H.ADC IDM_norm_cooc.H.ADC Inv_var_cooc.H.ADC
## [1,] -0.3373427   -0.41942235   -0.2312376
## [2,] -0.6870110   -0.29717220   -0.7032184
## [3,]  0.2051580   -0.06370859   0.2051580
## [4,]  0.1921714   0.27065942   0.1792170
## [5,] -0.2971722   -0.28389090   -0.3644243
## [6,]  0.3508513   0.23123752   0.3644243
##      Correlation_cooc.H.ADC Autocorrelation_cooc.H.ADC Tendency_cooc.H.ADC
## [1,]          -0.7529954   -1.487910e+00   -0.8404111
## [2,]          -0.4473933   5.932479e-01   -0.4900236
## [3,]          0.2051580   -2.574751e-01   0.3508513
## [4,]          0.4900236   -6.436293e-17   0.1020415
## [5,]          -0.5482987   -4.055602e-01   -0.8224296
## [6,]          0.5044297   -1.273346e-02   0.4615096

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##      Shade_cooc.H.ADC Prominence_cooc.H.ADC IC1_d.H.ADC IC2_d.H.ADC
## [1,] 0.5482987 -0.93476628 -1.1793914 0.50442967
## [2,] -1.6635205 -0.78723867 0.2971724 -0.01273346
## [3,] 1.2596485 0.51894110 0.1020416 0.14052475
## [4,] -0.1276767 -0.01273346 0.4757185 -0.15339601
## [5,] -0.8960694 -0.91524677 0.3644245 -0.03820863
## [6,] -0.7872387 0.28389090 -0.4757183 0.37806448
##      Coarseness_vdif.H.ADC Contrast_vdif.H.ADC Busyness_vdif.H.ADC
## [1,] 6.709821e-01 0.03820863 -1.6635205
## [2,] 3.820853e-02 -0.08924999 -0.7362013
## [3,] -1.276769e-01 -1.06032943 -0.3105060
## [4,] -3.238955e-01 -1.34894519 0.2181792
## [5,] -7.647320e-02 -0.01273346 -0.5044297
## [6,] -1.147554e-07 -1.28828023 -0.6394275
##      Complexity_vdif.H.ADC Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC
## [1,] 5.095448e-02 1.3180073 0.05095439 -0.6709820
## [2,] -1.405248e-01 0.7362013 0.02546889 -0.6551233
## [3,] -1.038266e+00 0.1662927 -0.41248158 0.2181792
## [4,] -1.348945e+00 -0.5335625 -0.53356273 0.2574751
## [5,] -6.436293e-17 0.2971722 -0.14052490 -0.3373427
## [6,] -1.259648e+00 0.6394275 -0.35085154 -0.1405248
##      GLNU_align.H.ADC RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC
## [1,] -1.4505021 -1.4505021 0.14052483 0.01273851
## [2,] -0.7529954 -0.7529954 0.08925006 -0.12767341
## [3,] -0.2971722 -0.3105060 -0.46150963 0.05096001
## [4,] 0.3373427 0.3373427 -0.56315481 -0.36442388
## [5,] -0.5781359 -0.5781359 -0.08924997 -0.21817705
## [6,] -0.5189411 -0.5189411 -0.28389092 -0.23123551
##      HGRE_align.H.ADC LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC
## [1,] 0.3105060 0.03821309 0.41942235 -3.917756e-01
## [2,] -0.6551233 -0.07646978 -0.07647307 -3.780647e-01
## [3,] -2.4286392 0.06371331 -2.42863924 -2.706596e-01
## [4,] -0.2181792 -0.37806428 -0.50442967 5.095454e-02
## [5,] -0.4194224 -0.25747366 -0.12767671 -2.574752e-01
## [6,] 0.2312375 -0.31050515 -0.01273346 2.756749e-08
##      HGLRE_align.H.ADC GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC
## [1,] -0.8047097 -0.03821078 2.838911e-01
## [2,] -0.8224296 -0.14696808 2.051581e-01
## [3,] 0.6084963 -0.22472047 -4.473934e-01
## [4,] -0.1020415 -0.47575501 -6.551235e-01
## [5,] -0.5482987 -0.14696808 6.658463e-08
## [6,] -0.5335625 -0.30385552 -2.838910e-01
##      GLVAR_align.H.ADC RLVAR_align.H.ADC Entropy_align.H.ADC SZSE.H.ADC
## [1,] 0.3508513 -0.59324787 -1.20528537 0.24433561
## [2,] 0.2051580 -0.54829867 -0.82242969 0.08925023
## [3,] -1.4879098 0.21817922 -0.05095444 -0.85866834
## [4,] -0.3644242 0.05095448 0.31050617 -0.39177532
## [5,] 0.1792170 -0.35085134 -0.54829874 -0.16629256
## [6,] -0.4473933 -0.15339601 -0.23123752 -0.65512338
##      LZSE.H.ADC LGLZE.H.ADC HGLZE.H.ADC SZLGE.H.ADC SZHGE.H.ADC LZLGE.H.ADC
## [1,] -0.85875773 0.19217133 -0.2971722 2.377814e-01 0.1405248 -0.75299544
## [2,] -0.80479542 0.03820853 -0.2051580 6.370858e-02 0.1148497 -0.60849632
## [3,] 0.62390401 -0.12126089 -2.8041692 -2.181794e-01 -2.1037376 0.06370859
## [4,] -0.05098619 -0.21817945 -0.2838909 -3.105063e-01 -0.4055602 -0.12767671

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## [5,] -0.17925794 -0.08925016 -1.3812290 -4.875143e-08 -1.2052851 -0.14052475
## [6,] 0.14050676 -0.41248169 0.3105060 -3.917756e-01 -0.5044297 0.54829867
##   LZHGE.H.ADC GLNU_area.H.ADC ZSNU.H.ADC ZSP.H.ADC GLNU_norm.H.ADC
## [1,] -0.78723867 -1.4505021 -1.4879695 0.3105064 0.0001161525
## [2,] -0.95464809 -0.7529954 -0.7530320 0.2181795 -0.2838687582
## [3,] 0.70321822 -0.3105060 -0.3239184 -1.2320127 -0.0126215246
## [4,] -0.02546898 0.3373427 0.3238925 -0.4333655 -0.4264086264
## [5,] 0.11484968 -0.5781359 -0.5932795 -0.1921713 -0.1533306504
## [6,] -0.10204149 -0.5335625 -0.5335922 -0.6238875 -0.2116180558
##   ZSNU_norm.H.ADC GLVAR_area.H.ADC ZSVAR.H.ADC Entropy_area.H.ADC
## [1,] 0.28389119 -0.03820863 -6.870142e-01 -1.41501808
## [2,] 0.17921729 0.44739330 -7.362047e-01 -0.85866816
## [3,] -1.25964882 -2.42863924 1.716510e+00 0.41942235
## [4,] -0.41942234 -0.51894110 -1.336426e-06 0.07647307
## [5,] -0.08924985 -0.01273346 -1.273483e-02 -0.53356248
## [6,] -0.80470987 -1.20528514 2.706588e-01 0.01273346
##   Max_cooc.W.ADC Average_cooc.W.ADC Variance_cooc.W.ADC DAVE_cooc.W.ADC
## [1,] 0.1662977 -8.772156e-01 0.3644242 0.28389090
## [2,] -0.1986587 4.473933e-01 -0.2181792 -0.05095448
## [3,] -0.2312360 -9.152468e-01 1.4150181 0.44739330
## [4,] -0.4900243 3.508513e-01 0.6551233 0.23123752
## [5,] -0.2971712 -6.436293e-17 0.1533960 0.33734270
## [6,] -0.3508508 7.529954e-01 1.8398097 1.01669574
##   DVAR_cooc.W.ADC DENT_cooc.W.ADC SAVE_cooc.W.ADC SVAR_cooc.W.ADC
## [1,] 0.85866816 0.1405248 -0.87721561 0.15339601
## [2,] -0.05095448 -0.1020415 0.46150957 -0.23123752
## [3,] 1.45050212 0.3780645 -0.91524677 1.41501808
## [4,] 0.32389526 0.1792170 0.39177534 0.73620133
## [5,] 0.29717220 0.2574751 0.01273346 0.06370859
## [6,] 1.52752054 0.6394275 0.70321822 1.83980971
##   SENT_cooc.W.ADC ASM_cooc.W.ADC Contrast_cooc.W.ADC
## [1,] -0.2312375 0.03821171 0.62388738
## [2,] -1.3489452 -0.13409891 0.02546898
## [3,] 0.5932479 -0.17921903 1.25964848
## [4,] 0.1792170 -0.41248879 0.32389526
## [5,] 0.1148497 -0.24433882 0.46150957
## [6,] -0.8772156 -0.36443054 1.61482620
##   Dissimilarity_cooc.W.ADC Inv_diff_cooc.W.ADC Inv_diff_norm_cooc.W.ADC
## [1,] 0.28389090 0.2706595 -0.67098197
## [2,] -0.05095448 -0.3508514 -0.05095448
## [3,] 0.44739330 -0.2312375 -0.36442422
## [4,] 0.23123752 -0.3373427 0.29717220
## [5,] 0.33734270 -0.6551234 -0.16629268
## [6,] 1.01669574 -0.9955881 -0.68701098
##   IDM_cooc.W.ADC IDM_norm_cooc.W.ADC Inv_var_cooc.W.ADC
## [1,] 0.2706595 -0.87721561 0.2443353
## [2,] -0.5482988 -0.06370859 -0.5631547
## [3,] -0.2838910 -0.51894110 -0.2312375
## [4,] -0.3917754 0.19217136 -0.4757183
## [5,] -0.5932480 -0.16629268 -0.7362013
## [6,] -0.9152469 -0.65512329 -0.8960694
##   Correlation_cooc.W.ADC Autocorrelation_cooc.W.ADC Tendency_cooc.W.ADC
## [1,] -0.8586682 -0.8224296 0.15339601
## [2,] -0.5781359 0.6084963 -0.23123752

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## [3,]          0.4900236      -0.8047097      1.41501808
## [4,]          0.4615096      0.6551233      0.73620133
## [5,]         -0.6084963      0.1148497      0.06370859
## [6,]          0.5932479      1.2320123      1.83980971
##   Shade_cooc.W.ADC Prominence_cooc.W.ADC IC1_d.W.ADC IC2_d.W.ADC
## [1,]      1.15426355      0.4055621     -1.0829209      0.4900236
## [2,]     -1.31800728     -0.1020407     -0.2181792      0.1921714
## [3,]      2.80416916      2.1037436     -0.4055602      0.2838909
## [4,]      0.47571828      0.7362041      0.4055602     -0.1148497
## [5,]      0.06370859      0.2706611     -0.3917753      0.2574751
## [6,]     -1.66352051      1.6635255     -1.2320123      0.6084963
##   Coarseness_vdif.W.ADC Contrast_vdif.W.ADC Busyness_vdif.W.ADC
## [1,]      0.35085134      1.8398097      -0.41942260
## [2,]      0.06370850      0.2312375      -0.82242999
## [3,]     -0.19217154      0.7362013      -0.05095456
## [4,]     -0.31050626     -0.2574751      -0.39177558
## [5,]     -0.03820876      0.4615096      -0.63942781
## [6,]     -0.07647320      1.2320123      -0.84041153
##   Complexity_vdif.W.ADC Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC
## [1,]     -0.5482987      1.34894519     -0.40556015     -0.1662927
## [2,]     -0.2051580      0.71961205     -0.02546898     -0.6084963
## [3,]      0.6870110      1.28828023     -0.17921704     -0.3373427
## [4,]      0.5189411      0.05095448     -0.29717220     -0.2971722
## [5,]      0.1662927      0.65512329     -0.03820863     -0.4900236
## [6,]      1.1793911      1.23201233      0.10204149     -0.8772156
##   GLNU_align.W.ADC RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC
## [1,]     -1.4505021     -1.5275205     -0.39177534      0.01273328
## [2,]     -0.8586682     -0.7529954      0.01273346     -0.34408956
## [3,]     -0.4333655     -0.2971722     -0.16629268     -0.32389562
## [4,]      0.1020415      0.3373427     -0.25747509     -0.07647329
## [5,]     -0.8772156     -0.5781359     -0.02546898     -0.39177575
## [6,]     -1.2052851     -0.5189411      0.10204149     -0.42638400
##   HGRE_align.W.ADC LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC
## [1,]     -0.7362013      0.01273324     -0.7362013      3.295782e-06
## [2,]      0.4615096     -0.33734313      0.4615096     -3.508505e-01
## [3,]     -0.7700043     -0.32389568     -0.7700043     -3.238942e-01
## [4,]      0.7529954     -0.08925027      0.7529954     -1.273025e-02
## [5,]      0.1405248     -0.39177581      0.1405248     -3.917748e-01
## [6,]      1.2320123     -0.42638406      1.2882802     -4.333653e-01
##   HGLRE_align.W.ADC GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC
## [1,]     -0.7362013      0.08924981     -0.37806451
## [2,]      0.4473933     -0.07647338      0.05095455
## [3,]     -0.7700043     -0.19217177     -0.08924996
## [4,]      0.7700043     -0.43336611     -0.23123751
## [5,]      0.1405248     -0.29717269      0.03820870
## [6,]      1.2052851     -0.53356317      0.21817933
##   GLVAR_align.W.ADC RLVAR_align.W.ADC Entropy_align.W.ADC SZSE.W.ADC
## [1,]      0.4333655     -0.1405238      0.2312375      0.37806457
## [2,]     -0.2181792     -0.4473935     -0.3238953     -0.47571838
## [3,]      1.1060782     -0.2181786     -0.1662927      0.41942244
## [4,]      0.7196121     -0.2051573      0.4473933      0.12767674
## [5,]      0.3644242     -0.3238950      0.2706594     -0.07647308
## [6,]      1.7747932     -0.5631553      0.6084963      0.29717226
##   LZSE.W.ADC LGLZE.W.ADC HGLZE.W.ADC SZLGE.W.ADC SZHGE.W.ADC LZLGE.W.ADC

```

```

## [1,] -1.2052851 0.02546896 -0.7362013 0.05095473 -0.7362013 -0.03820863
## [2,] -0.4194224 -0.33734299 0.4615096 -0.33734264 0.4757183 -0.39177534
## [3,] 0.2443353 -0.32389553 -0.7700043 -0.32389519 -0.7700043 -0.31050605
## [4,] -0.6870110 -0.24433553 0.7529954 -0.25747499 0.7529954 -0.01273346
## [5,] -0.1533960 -0.39177567 0.1405248 -0.39177531 0.1405248 -0.41942235
## [6,] -1.0166957 -0.41942269 1.2320123 -0.41942233 1.2320123 -0.46150957
##      LZHGE.W.ADC GLNU_area.W.ADC ZSNU.W.ADC    ZSP.W.ADC GLNU_norm.W.ADC
## [1,] -0.7872387      -1.4505021 -1.3812290 0.49002356      0.03820875
## [2,] 0.4473933      -0.8404111 -0.7529954 -0.32389526     -0.11484963
## [3,] -0.7362013      -0.4615096 -0.2838909 0.29717220      0.29717244
## [4,] 0.6709820      0.1148497 0.3780645 0.25747509     -0.43336560
## [5,] 0.1662927      -0.9347663 -0.5781359 -0.06370859      0.33061178
## [6,] 1.2052851      -1.1793911 -0.5189411 0.44739330     -0.51894124
##      ZSNU_norm.W.ADC GLVAR_area.W.ADC ZSVAR.W.ADC Entropy_area.W.ADC
## [1,] 0.43336550      0.4333655 -0.8047097     -1.66352051
## [2,] -0.16629268     -0.2181792 -0.4055602     -0.39177534
## [3,] -0.57813595      1.0603294 0.4194224      0.25747509
## [4,] 0.17921704      0.7196121 -0.4473933     0.39177534
## [5,] -0.02546898      0.3644242 -0.1533960      0.03820863
## [6,] 0.35085134      1.7747932 -0.7032182      0.56315472

```

## K-Means Clustering

K-means clustering is the most commonly used unsupervised machine learning algorithm for partitioning a given data set into a set of k groups (i.e. k clusters). The basic idea behind k-means clustering consists of defining clusters so that the total intra-cluster variation (known as total within-cluster variation) is minimized.

We can compute k-means in R with the `kmeans()` function. Here will group the data into three clusters (`centers = 3`). The `kmeans` function has an `nstart` option that attempts multiple initial configurations and reports on the best one. Adding `nstart = 25` will generate 25 initial configurations.

```

k3 <- kmeans(df, centers = 3, iter.max = 100, nstart = 100)
str(k3)

## List of 9
## $ cluster      : int [1:197] 2 2 2 2 2 2 2 2 2 ...
## $ centers       : num [1:3, 1:429] -0.2464 0.0654 0.0821 0.052 -0.0457 ...
##   ..- attr(*, "dimnames")=List of 2
##   ...$ : chr [1:3] "1" "2" "3"
##   ...$ : chr [1:429] "Failure" "Entropy_cooc.W.ADC" "GLNU_align.H.PET" "Min_hist.PET" ...
## $ totss        : num 84084
## $ withinss     : num [1:3] 10413 24997 13420
## $ tot.withinss: num 48830
## $ betweenss    : num 35254
## $ size         : int [1:3] 44 103 50
## $ iter         : int 3

```

```

## $ ifault      : int 0
## - attr(*, "class")= chr "kmeans"

```

Print the result and we see that our groupings resulted in 3 cluster sizes of 44, 50, 103. We see the cluster centers (means) for the two groups across many variables starting from Failure, Entropy\_cooc.W.ADC, GLNU\_align.H.PET and so on.

k3

```

## 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 -0.24638949      0.05200710     0.126697686   0.04585696   0.08504594
## 2  0.06537718     -0.04573823    -0.009433942  -0.43645422  -0.46197403
## 3  0.08214575      0.04845450    -0.092060043   0.85874157   0.87682607
##   Mean_hist.PET Variance_hist.PET Standard_Deviation_hist.PET Skewness_hist.PET
## 1    0.08479383      0.2279436       0.0410318     -0.5428415
## 2   -0.45868782     -0.3330976       -0.4359917     -0.1564058
## 3    0.87027835      0.4855907       0.8620350     0.7998965
##   Kurtosis_hist.PET Energy_hist.PET Entropy_hist.PET AUC_hist.PET H_suv.PET
## 1   -0.06878862     -1.2406345     -0.1535503   -1.20376496  -0.1721421
## 2    0.04878509      0.1319279     -0.5425300   -0.09790924  -0.3530821
## 3   -0.03996330      0.8199868     1.2527361   1.26100621   0.8788341
##   Volume.PET X3D_surface.PET ratio_3ds_vol.PET ratio_3ds_vol_norm.PET
## 1    0.4518410      0.1229739     -1.032381320     -0.92503862
## 2   -0.4473168     -0.3137553     -0.002504806     -0.05148286
## 3    0.5238526      0.5381188      0.913655462     0.92008868
##   irregularity.PET tumor_length.PET Compactness_v1.PET Compactness_v2.PET
## 1   -0.9587467     -0.3148322     -1.06130280     0.00075632
## 2   -0.2025772     -0.3577728     -0.04053042     -0.33148005
## 3    1.2610062      1.0140643      1.01743912     0.68218335
##   Spherical_disproportion.PET Sphericity.PET Asphericity.PET Center_of_mass.PET
## 1   -0.92503862      0.0083911     -0.92336330     -0.1664062
## 2   -0.05148286     -0.4090411     -0.04633856     -0.2830070
## 3    0.92008868      0.8352405      0.90801714     0.7294319
##   Max_3D_diam.PET Major_axis_length.PET Minor_axis_length.PET
## 1    0.4049083      0.2923557      0.09513965
## 2   -0.5666852     -0.5486413      -0.54545457
## 3    0.8110522      0.8729280      1.03991352
##   Least_axis_length.PET Elongation.PET Flatness.PET Max_cooc.L.PET
## 1    0.2611157     -0.8083506     -0.5663013    -1.2377046
## 2   -0.5446258     -0.2539493     -0.3408235     0.1175852
## 3    0.8921472      1.2344841     1.2004416     0.8469546
##   Average_cooc.L.PET Variance_cooc.L.PET Entropy_cooc.L.PET DAVE_cooc.L.PET
## 1   -0.4959192      -0.6739093     -0.2685377     -0.6453081
## 2   -0.3625706      -0.1758933     -0.4974238     -0.2725761
## 3    1.1833043      0.9553804      1.2610062     1.1293779
##   DVAR_cooc.L.PET DENT_cooc.L.PET SAVE_cooc.L.PET SVAR_cooc.L.PET
## 1   -0.6767720     -0.7056993     -0.4941932     -0.6640316
## 2   -0.1910234     -0.3106751     -0.3631785     -0.1977607
## 3    0.9890675      1.2610062     1.1830377     0.9917348

```

```

##    SENT_cooc.L.PET ASM_cooc.L.PET Contrast_cooc.L.PET Dissimilarity_cooc.L.PET
## 1      -0.9317152     -1.2294851      -0.5547851      -0.6453081
## 2      -0.2141247      0.1319836      -0.1507953      -0.2725761
## 3      1.2610062      0.8100606      0.7988492      1.1293779
##    Inv_diff_cooc.L.PET Inv_diff_norm_cooc.L.PET IDM_cooc.L.PET
## 1      -0.7775483      -0.8141946      -0.8857651
## 2      -0.2739537      -0.2643276      -0.1969052
## 3      1.2485871      1.2610062      1.1850979
##    IDM_norm_cooc.L.PET Inv_var_cooc.L.PET Correlation_cooc.L.PET
## 1      -0.9675063      -0.9013253      -0.3586545
## 2      -0.1988353      -0.1927562      -0.3350398
## 3      1.2610062      1.1902440      1.0057979
##    Autocorrelation_cooc.L.PET Tendency_cooc.L.PET Shade_cooc.L.PET
## 1      -0.4282134      -0.6640316      -0.37689090
## 2      -0.2523420      -0.1977607      -0.06389272
## 3      0.8966523      0.9917348      0.46328300
##    Prominence_cooc.L.PET IC1_.L.PET IC2_.L.PET Coarseness_vdif_.L.PET
## 1      -0.64475251     -0.02866924     -1.001224      -1.2476681
## 2      -0.06490617     0.28950284     -0.182536      0.1389880
## 3      0.70108893     -0.57114691     1.257101      0.8116326
##    Contrast_vdif_.L.PET Busyness_vdif_.L.PET Complexity_vdif_.L.PET
## 1      -0.7058882      0.2287172      -0.8095809
## 2      -0.0251084      -0.3710415      -0.1975675
## 3      0.6729049      0.5630744      1.1194203
##    Strength_vdif_.L.PET SRE_align.L.PET LRE_align.L.PET GLNU_align.L.PET
## 1      -0.8803918      -1.2869226      -0.7774763      0.4274795
## 2      0.1338226      -0.0623856      -0.2800131      -0.3996385
## 3      0.4990703      1.2610062      1.2610062      0.4470734
##    RLNU_align.L.PET RP_align.L.PET LGRE_align.L.PET HGRE_align.L.PET
## 1      0.4745056      -1.2784424      -1.1301238429     -0.4400459
## 2      -0.4023296      -0.0660082      0.0003068724      -0.2607318
## 3      0.4112341      1.2610062      0.9938768247      0.9243479
##    LGSRE_align.L.PET HGSRE_align.L.PET LGHRE_align.L.PET HGLRE_align.L.PET
## 1      -1.137863173     -0.4547746      -1.0946362665     -0.3821475
## 2      0.001502125     -0.2534191      -0.0002882839     -0.2916630
## 3      0.998225215     0.9222450      0.9638737792      0.9371156
##    GLNU_norm_align.L.PET RLNU_norm_align.L.PET GLVAR_align.L.PET
## 1      -1.29006007     -1.22389485     -0.6241077
## 2      0.05026552      -0.08931007     -0.2128020
## 3      1.03170588      1.26100621      0.9875870
##    RLVAR_align.L.PET Entropy_align.L.PET SZSE.L.PET LZSE.L.PET LGLZE.L.PET
## 1      -1.10198903     -0.3048233     -1.1703808     -0.2560081     -1.141762407
## 2      -0.02325062     -0.4819232     -0.1121704     -0.4488779     -0.002221956
## 3      1.01764663      1.2610062      1.2610062      1.1499756      1.009328147
##    HGLZE.L.PET SZLGE.L.PET SZHGE.L.PET LZLGE.L.PET LZHGE.L.PET GLNU_area.L.PET
## 1      -0.4547108     -1.169840211     -0.5176669     -0.93017679     -0.2706204      0.4167183
## 2      -0.2603457     0.001672616     -0.2328767     -0.02473818     -0.3087426      -0.4004704
## 3      0.9364576     1.026013796     0.9352729     0.86951623     0.8741557      0.4582570
##    ZSNU.L.PET ZSP.L.PET GLNU_norm.L.PET ZSNU_norm.L.PET GLVAR_area.L.PET
## 1      0.4716323     -1.0708645     -1.28850827     -1.0111507     -0.6380485
## 2      -0.4105445     -0.1546823     0.04990501     -0.1801911     -0.2148491
## 3      0.4306853     1.2610062      1.03108296     1.2610062      1.0040719
##    ZSVAR.L.PET Entropy_area.L.PET Max_cooc.H.PET Average_cooc.H.PET
## 1      -0.5205423     -0.2300047     -1.0446699     -0.8674055

```

```

## 2 -0.2133959      -0.5138845      0.1789068      -0.2415968
## 3  0.8976727      1.2610062      0.5507615      1.2610062
##   Variance_cooc.H.PET Entropy_cooc.H.PET DAVE_cooc.H.PET DVAR_cooc.H.PET
## 1 -0.1076677      -0.1513560      -0.3370926      -0.3491879
## 2 -0.5538043      -0.5131234      -0.4673835      -0.4582690
## 3  1.2355844      1.1902276      1.2594515      1.2513196
##   DENT_cooc.H.PET SAVE_cooc.H.PET SVAR_cooc.H.PET SENT_cooc.H.PET
## 1 -0.1766716      -0.7375421      -0.2181004      -0.7930772
## 2 -0.5105001      -0.2970724      -0.5089699      -0.1374373
## 3  1.2071013      1.2610062      1.2404064      0.9810288
##   ASM_cooc.H.PET Contrast_cooc.H.PET Dissimilarity_cooc.H.PET
## 1 -1.1508857      -0.3228096      -0.3370926
## 2  0.2173848      -0.4441699      -0.4673835
## 3  0.5649668      1.1990625      1.2594515
##   Inv_diff_cooc.H.PET Inv_diff_norm_cooc.H.PET IDM_cooc.H.PET
## 1 -0.9451290      -1.1631295      -0.92276752
## 2 -0.1146295      -0.1152681      -0.05603959
## 3  1.0678502      1.2610062      0.92747697
##   IDM_norm_cooc.H.PET Inv_var_cooc_.H.PET Correlation_cooc.H.PET
## 1 -1.2317778      -1.13943252     -0.2939734
## 2 -0.0859426      0.03016403     -0.3677423
## 3  1.2610062      0.94056271     1.0162458
##   Autocorrelation_cooc.H.PET Tendency_cooc.H.PET Shade_cooc.H.PET
## 1           -0.8764561     -0.08218198     0.0130268
## 2           -0.2312947     -0.55524643     0.2897603
## 3           1.2477485      1.21612779     -0.6083698
##   Prominence_cooc.H.PET IC1_d.H.PET IC2_d.H.PET Coarseness_vdif.H.PET
## 1           0.05661571    -0.5772033     -0.3675008     -1.2296950
## 2           -0.47608722    0.3322440     -0.4237839     0.1366371
## 3           0.93091786    -0.1764838     1.1963955     0.8006591
##   Contrast_vdif.H.PET Busyness_vdif.H.PET Complexity_vdif.H.PET
## 1           -0.56987256    0.5445366     -0.91622789
## 2           -0.05878702    -0.4359746     -0.07510634
## 3           0.62258911    0.4189154     0.96099961
##   Strength_vdif.H.PET SRE_align.H.PET LRE_align.H.PET RLNU_align.H.PET
## 1           -0.9377278    -0.5658223     -0.7057473     0.5003948
## 2           0.2376470     -0.3704284     -0.2154755     -0.4139000
## 3           0.3356476     1.2610062     1.0649372     0.4122865
##   RP_align.H.PET LGRE_align.H.PET HGRE_align.H.PET LGSRE_align.H.PET
## 1           -0.5202500    -1.1999846     -0.7741663     -1.2007644
## 2           -0.3898962    0.1184958     -0.2737050     0.1188289
## 3           1.2610062    0.8118850     1.2450986     0.8118850
##   HGSRE_align.H.PET LGHRE_align.H.PET HGLRE_align.H.PET GLNU_norm_align.H.PET
## 1           -0.6717061    -1.1998696     -0.5798024     -1.02132727
## 2           -0.3251965    0.1173371     -0.1801486     0.03759345
## 3           1.2610062    0.8141708     0.8813322     0.82132550
##   RLNU_norm_align.H.PET GLVAR_align.H.PET RLVAR_align.H.PET Entropy_align.H.PET
## 1           -0.4214434    -0.07611098    -0.66450875    -0.09446914
## 2           -0.4321049    -0.54797206    -0.01910859    -0.57178319
## 3           1.2610062    1.19580011    0.62413140     1.26100621
##   SZSE.H.PET LZSE.H.PET LGLZE.H.PET HGLZE.H.PET SZLGE.H.PET SZHGE.H.PET
## 1 -0.4470299 -0.2715817 -1.1998381 -0.6201846 -1.2021333 -0.4714018
## 2 -0.4032952 -0.0746649  0.1186081 -0.3370729  0.1196279 -0.3808504
## 3  1.2241745  0.3928016  0.8115249  1.2401327  0.8114437  1.1993854

```

```

##   LZLGE.H.PET   LZHGE.H.PET GLNU_area.H.PET ZSNU.H.PET   ZSP.H.PET
## 1 -0.9511959 -0.403751927      0.4030738  0.4712095 -0.2763891
## 2  0.1835682  0.002524456     -0.4066093 -0.3660541 -0.3881463
## 3  0.4589019  0.350101318      0.4829101  0.3394070  1.0428037
##   GLNU_norm.H.PET ZSNU_norm.H.PET GLVAR_area.H.PET ZSVAR_H.PET
## 1    -1.0083639     -0.3167062     -0.1076021 -0.40818170
## 2     0.0191874     -0.3843304     -0.5270962  0.02643966
## 3     0.8478342     1.0704220     1.1805080  0.30473420
##   Entropy_area.H.PET Max_cooc.W.PET Average_cooc.W.PET Variance_cooc.W.PET
## 1    -0.05109651    -1.2468037     0.1122544  0.2337219
## 2    -0.59031130     0.2203858     -0.4616517 -0.3256100
## 3     1.26100621     0.6431925     0.8522186  0.4650814
##   Entropy_cooc.W.PET DAVE_cooc.W.PET DVAR_cooc.W.PET DENT_cooc.W.PET
## 1    -0.1073673     0.006743546     0.1971657 -0.1804813
## 2    -0.5588924     -0.424423328     -0.3224611 -0.5233676
## 3     1.2458016     0.868377736     0.4907641  1.2369607
##   SAVE_cooc.W.PET SVAR_cooc.W.PET SENT_cooc.W.PET ASM_cooc.W.PET
## 1     0.1157009     0.2550944     -0.3620001 -1.2643186
## 2    -0.4625522     -0.3286516     -0.4564338  0.1986421
## 3     0.8510408     0.4525392     1.2588138  0.7033977
##   Contrast_cooc.W.PET Dissimilarity_cooc.W.PET Inv_diff_cooc.W.PET
## 1     0.1722521     0.006743546     -0.9382274
## 2    -0.3226168     -0.424423328     -0.1656669
## 3     0.5130087     0.868377736     1.1669140
##   Inv_diff_norm_cooc.W.PET IDM_cooc.W.PET IDM_norm_cooc.W.PET
## 1    -0.8564369     -0.91054172     -0.9835407
## 2    -0.2462824     -0.08803608     -0.1919857
## 3     1.2610062     0.98263103     1.2610065
##   Inv_var_cooc.W.PET Correlation_cooc.W.PET Autocorrelation_cooc.W.PET
## 1    -0.9377635     -0.3429057     0.3145434
## 2    -0.1191630     -0.3424528     -0.3622375
## 3     1.0707077     1.0072099     0.4694111
##   Tendency_cooc.W.PET Shade_cooc.W.PET Prominence_cooc.W.PET IC1_d.W.PET
## 1     0.2550944     0.2261518     0.3340363 -0.6262563
## 2    -0.3286516     -0.1931742     -0.2587149  0.3873344
## 3     0.4525392     0.1989252     0.2390007 -0.2468033
##   IC2_d.W.PET Coarseness_vdif.W.PET Contrast_vdif.W.PET Busyness_vdif.W.PET
## 1    -0.4870084     -1.2493989     -0.3598249 -0.1345930
## 2    -0.3973578     0.1744151     -0.2219072 -0.1647786
## 3     1.2471245     0.7401759     0.7737748  0.4578856
##   Complexity_vdif.W.PET Strength_vdif.W.PET SRE_align.W.PET LRE_align.W.PET
## 1     0.2968367     -0.41666689    -0.7719393 -0.7990212
## 2     -0.3066483     -0.09774272    -0.2823784 -0.2477785
## 3     0.3704793     0.56801686     1.2610062  1.2135624
##   GLNU_align.W.PET RLNU_align.W.PET RP_align.W.PET LGRE_align.W.PET
## 1     0.2966597     0.4907296     -0.6843643 -0.99492983
## 2     -0.3664176     -0.4106382     -0.3197891  0.04876726
## 3     0.4937597     0.4140726     1.2610062  0.77507770
##   HGRE_align.W.PET LGSRE_align.W.PET HGSRE_align.W.PET LGHRE_align.W.PET
## 1     0.3173854     -1.0143302     0.3121082 -0.89228814
## 2     -0.3650626     0.0359557     -0.3577645  0.07777343
## 3     0.4727298     0.8185419     0.4623397  0.62500029
##   HGLRE_align.W.PET GLNU_norm_align.W.PET RLNU_norm_align.W.PET
## 1     0.3287373     -1.14518054    -0.5352664

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## 2      -0.3797422      0.09076661      -0.3834814
## 3       0.4929801      0.82077967      1.2610062
## GLVAR_align.W.PET RLVAR_align.W.PET Entropy_align.W.PET SZSE.W.PET
## 1      0.2471427     -0.88234771     -0.0890419  -0.5462398
## 2     -0.3403325      0.03915467     -0.5741016  -0.3787938
## 3      0.4835994      0.69580736      1.2610062  1.2610062
## LZSE.W.PET LGLZE.W.PET HGLZE.W.PET SZLGE.W.PET SZHGE.W.PET LZLGE.W.PET
## 1   -0.57464968  -1.00132489      0.3032912  -1.08631389      0.2678236  -0.7103528
## 2   -0.05497139      0.03611711     -0.3615562  0.01378553     -0.3414232  0.1222846
## 3    0.61893278      0.80676466      0.4779095  0.92755803      0.4676471  0.3732041
## LZHGE.W.PET GLNU_area.W.PET ZSNU.W.PET ZSP.W.PET GLNU_norm.W.PET
## 1    0.2912848      0.3500241      0.4794367  -0.4314773     -1.14253625
## 2   -0.3858164      -0.3916938     -0.3954672  -0.4244237      0.07912406
## 3    0.5384512      0.4988679      0.3927581  1.2540128      0.84243633
## ZSNU_norm.W.PET GLVAR_area.W.PET ZSVAR.W.PET Entropy_area.W.PET Min_hist.ADC
## 1   -0.3990774      0.2292427     -0.57425688     -0.05591386  -0.2864881
## 2   -0.4345812      -0.3295647      0.05368149     -0.58825341  -0.1380119
## 3    1.2464255      0.4771697      0.39476218      1.26100621  0.5364140
## Max_hist.ADC Mean_hist.ADC Variance_hist.ADC Standard_Deviation_hist.ADC
## 1   -0.4641644      -0.3892240     -0.57365875     -0.6682174
## 2   -0.4114837      -0.4407905     -0.09472315     -0.2638962
## 3    1.2561211      1.2505455      0.69994940      1.1316575
## Skewness_hist.ADC Kurtosis_hist.ADC Energy_hist.ADC Entropy_hist.ADC
## 1   -0.06417418      0.05493307     -1.2257127     -0.4451103
## 2   -0.18767783      -0.16671301      0.1307215     -0.4219947
## 3    0.44308961      0.29508771      0.8093408      1.2610062
## AUC_hist.ADC Volume.ADC X3D_surface.ADC ratio_3ds_vol.ADC
## 1   -0.8193435      0.4140316     -0.0606709     -0.7500699
## 2   -0.2621283     -0.4233601     -0.2753462     -0.1974654
## 3    1.2610066      0.5077740      0.6206037      1.0668403
## ratio_3ds_vol_norm.ADC irregularity.ADC Compactness_v1.ADC Compactness_v2.ADC
## 1   -0.5669541      -0.6593353     -1.28088272     -0.7096110
## 2   -0.3699450      -0.3304811      0.03142066     -0.2321898
## 3    1.2610062      1.2610062      1.06245022      1.1027687
## Spherical_disproportion.ADC Sphericity.ADC Asphericity.ADC Center_of_mass.ADC
## 1   -0.5669541      -0.8269058     -0.4565552     -0.30911982
## 2   -0.3699450      -0.2588976     -0.3557791     -0.08729681
## 3    1.2610062      1.2610062      1.1346735      0.45185687
## Max_3D_diam.ADC Major_axis_length.ADC Minor_axis_length.ADC
## 1   -0.2274094      -0.3099045     -0.2275549
## 2   -0.3644002      -0.4005435     -0.3813531
## 3    0.9507846      1.0978355      0.9858357
## Least_axis_length.ADC Elongation.ADC Flatness.ADC Max_cooc.L.ADC
## 1   -0.1585236      -0.4558866     -0.4355862     -1.21985793
## 2   -0.3769359      -0.4157332     -0.4105727      0.08253485
## 3    0.9159888      1.2575906      1.2290955      0.90345319
## Average_cooc.L.ADC Variance_cooc.L.ADC Entropy_cooc.L.ADC DAVE_cooc.L.ADC
## 1   -0.3336411      -0.6744625     -0.6250607     -0.6279979
## 2   -0.4661050      -0.1419750     -0.3451227     -0.2977163
## 3    1.2537804      0.8859954      1.2610062      1.1659338
## DVAR_cooc.L.ADC DENT_cooc.L.ADC SAVE_cooc.L.ADC SVAR_cooc.L.ADC
## 1   -0.6797727      -0.7169051     -0.3333451     -0.6649414
## 2   -0.1347764      -0.3058882     -0.4662314     -0.1329086
## 3    0.8758394      1.2610062      1.2537804      0.8589402

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##    SENT_cooc.L.ADC ASM_cooc.L.ADC Contrast_cooc.L.ADC Dissimilarity_cooc.L.ADC
## 1      -0.3989158     -1.2087035      -0.5911236      -0.6279979
## 2      -0.3230180      0.1097121      -0.1426598      -0.2977163
## 3      1.0164629      0.8376521      0.8140680      1.1659338
##    Inv_diff_cooc.L.ADC Inv_diff_norm_cooc.L.ADC IDM_cooc.L.ADC
## 1      -0.8112094      -1.0339652      -0.8263762
## 2      -0.2645293      -0.1704452      -0.2355299
## 3      1.2587946      1.2610066      1.2124027
##    IDM_norm_cooc.L.ADC Inv_var_cooc.L.ADC Correlation_cooc.L.ADC
## 1      -1.1872975      -0.8131001      -0.6737162
## 2      -0.1049439      -0.2449825      -0.2080744
## 3      1.2610062      1.2201921      1.0215036
##    Autocorrelation_.L.ADC Tendency_cooc.L.ADC Shade_.L.ADC Prominence_cooc.L.ADC
## 1      -0.3098370      -0.6649414     -0.06135605     -0.632465720
## 2      -0.3809032      -0.1329086     -0.08932906      0.009646047
## 3      1.0573171      0.8589402     0.23801119      0.536698976
##    IC1_.L.ADC IC2_.L.ADC Coarseness_vdif_.L.ADC Contrast_vdif_.L.ADC
## 1 -0.3289130 -0.8510251      -1.2315126      -0.755856168
## 2  0.4224645 -0.2431110      0.1832338      -0.004267165
## 3 -0.5808334  1.2497107      0.7062694      0.673943788
##    Busyness_vdif_.L.ADC Complexity_vdif_.L.ADC Strength_vdif_.L.ADC
## 1      -0.4836846      -0.6206652      -0.35785747
## 2      -0.1267904      -0.2880789      -0.04141227
## 3      0.6868307      1.1396278      0.40022386
##    SRE_align.L.ADC LRE_align.L.ADC GLNU_align.L.ADC RLNU_align.L.ADC
## 1      -1.22921678     -0.7709996      0.009709534     -0.04687914
## 2      -0.08703695     -0.2827799     -0.240932986     -0.22553738
## 3      1.26100689     1.2610062      0.487777562      0.50586065
##    RP_align.L.ADC LGRE_align.L.ADC HGRE_align.L.ADC LGSRE_align.L.ADC
## 1      -1.1855243     -1.2395592     -0.3623635     -1.239364
## 2      -0.1057014      0.1449922     -0.3947405      0.144266
## 3      1.2610062      0.7921281     1.1320453      0.793452
##    HGSRE_align.L.ADC LGHRE_align.L.ADC HGLRE_align.L.ADC GLNU_norm_align.L.ADC
## 1      -0.3720836      -1.2411265      -0.3209441     -1.22721402
## 2      -0.3915385      0.1519871      -0.4122198     -0.04116189
## 3      1.1340029      0.7790980      1.1316036      1.16474183
##    RLNU_norm_align.L.ADC GLVAR_align.L.ADC RLVAR_align.L.ADC Entropy_align.L.ADC
## 1      -1.0572248      -0.6888250      -0.99448887     -0.7419215
## 2      -0.1605091      -0.1603817      -0.09828869     -0.2952016
## 3      1.2610066      0.9365524      1.07762492      1.2610062
##    SZSE.L.ADC LZSE.L.ADC LGLZE.L.ADC HGLZE.L.ADC SZLGE.L.ADC SZHGE.L.ADC
## 1 -1.0522267 -0.4389908 -1.2390250 -0.3644243 -1.2356743 -0.3749926
## 2 -0.1626442 -0.3956262  0.1400977 -0.4020896  0.1377293 -0.3952206
## 3  1.2610065  1.2013018  0.8017407  1.1489979  0.8036711  1.1441480
##    LZLGE.L.ADC LZHGE.L.ADC GLNU_area.L.ADC ZSNU.L.ADC ZSP.L.ADC GLNU_norm.L.ADC
## 1 -1.2340635 -0.2673208 -0.003034725 -0.0462503 -0.8818584 -1.24469430
## 2  0.1873437 -0.4083600 -0.238174927 -0.2279717 -0.2354227 -0.03059644
## 3  0.7000477  1.0764639  0.493310907  0.5103219  1.2610062  1.15835965
##    ZSNU_norm.L.ADC GLVAR_area.L.ADC ZSVAR.L.ADC Entropy_area.L.ADC
## 1      -0.8424410      -0.6981154      -0.3889422      -0.6973508
## 2      -0.2522613      -0.1628163      -0.2001315      -0.3142415
## 3      1.2610063      0.9497431      0.7545401      1.2610062
##    Max_cooc.H.ADC Average_cooc.H.ADC Variance_cooc.H.ADC Entropy_cooc.H.ADC
## 1      -1.2204511      -0.4651563      -0.3955399      -0.2458259

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## 2      0.1227091      -0.4134314      -0.4431704      -0.5071259
## 3      0.8212163      1.2610062      1.2610062      1.2610062
## DAVE_cooc.H.ADC DVAR_cooc.H.ADC DENT_cooc.H.ADC SAVE_cooc.H.ADC
## 1      -0.4109838      -0.4410205      -0.4877151      -0.4577571
## 2      -0.4365730      -0.4225223      -0.4037945      -0.4165922
## 3      1.2610062      1.2584940      1.2610060      1.2610062
## SVAR_cooc.H.ADC SENT_cooc.H.ADC ASM_cooc.H.ADC Contrast_cooc.H.ADC
## 1      -0.5527784      -0.4829811      -1.2196578      -0.3612323
## 2      -0.3760006      -0.4058169      0.1277874      -0.4344390
## 3      1.2610062      1.2610062      0.8100568      1.2128288
## Dissimilarity_cooc.H.ADC Inv_diff_cooc.H.ADC Inv_diff_norm_cooc.H.ADC
## 1      -0.4109838      -1.180666      -1.1778345
## 2      -0.4365730      -0.107623      -0.1089863
## 3      1.2610062      1.260690      1.2610062
## IDM_cooc.H.ADC IDM_norm_cooc.H.ADC Inv_var_cooc.H.ADC Correlation_cooc.H.ADC
## 1      -1.20639848     -1.21325796     -1.23708979     -0.6759406
## 2      -0.08635799     -0.09385398     -0.07470963     -0.2054811
## 3      1.23952812     1.26100621     1.24254086     1.0181188
## Autocorrelation_cooc.H.ADC Tendency_cooc.H.ADC Shade_cooc.H.ADC
## 1      -0.5596337      -0.5527784      -0.0402483
## 2      -0.3730721      -0.3760006      -0.1719959
## 3      1.2610062      1.2610062      0.3897301
## Prominence_cooc.H.ADC IC1_d.H.ADC IC2_d.H.ADC Coarseness_vdif.H.ADC
## 1      -0.5278320     -0.2932829     -0.7751245     -1.2283655
## 2      -0.3866573     0.3519148     -0.2796836     0.1823866
## 3      1.2610062     -0.4668555     1.2582578     0.7052453
## Contrast_vdif.H.ADC Busyness_vdif.H.ADC Complexity_vdif.H.ADC
## 1      -0.4519574      -0.2333788      -0.3779299
## 2      -0.4189158      -0.1962940      -0.4478493
## 3      1.2606890      0.6097390      1.2551479
## Strength_vdif.H.ADC SRE_align.H.ADC LRE_align.H.ADC GLNU_align.H.ADC
## 1      -0.31471124     -1.28600125     -1.0985272     -0.05173676
## 2      -0.03718193     -0.06277931     -0.1428652     -0.22768808
## 3      0.35354067     1.26100647     1.2610062     0.51456579
## RLNU_align.H.ADC RP_align.H.ADC LGRE_align.H.ADC HGRE_align.H.ADC
## 1      -0.04867056     -1.27361922     -1.27765222    -0.5639565
## 2      -0.23013578     -0.06806875     0.03987414     -0.3712255
## 3      0.51690981     1.26100654     1.04219323     1.2610062
## LGSRE_align.H.ADC HGSRE_align.H.ADC LGHRE_align.H.ADC HGLRE_align.H.ADC
## 1      -1.27663363     -0.4695871     -1.272360535    -0.3919663
## 2      0.04337941     -0.4115386     0.007475531    -0.4446970
## 3      1.03407602     1.2610062     1.104277676     1.2610062
## GLNU_norm_align.H.ADC RLNU_norm_align.H.ADC GLVAR_align.H.ADC
## 1      -1.25810344     -1.202406     -0.4587517
## 2      0.05820082     -0.098490     -0.4161673
## 3      0.98723733     1.261007     1.2610062
## RLVAR_align.H.ADC Entropy_align.H.ADC SZSE.H.ADC LZSE.H.ADC LGLZE.H.ADC
## 1      -1.234720843    -0.7049199    -1.1335874    -0.7280354    -1.26510163
## 2      0.006019786    -0.3110083    -0.1278884    -0.3011638    0.04242133
## 3      1.074153583    1.2610065    1.2610069    1.2610685    1.02590149
## HGLZE.H.ADC SZLGE.H.ADC SZHGE.H.ADC LZLGE.H.ADC LZHGE.H.ADC GLNU_area.H.ADC
## 1      -0.6239460    -1.25721240    -0.4628732    -1.178895154   -0.5645359    -0.0463249
## 2      -0.3455989    0.05397137    -0.4144067    -0.003059701   -0.3705110    -0.2300161
## 3      1.2610062    0.99516588    1.2610062    1.043730718   1.2600443    0.5145991

```

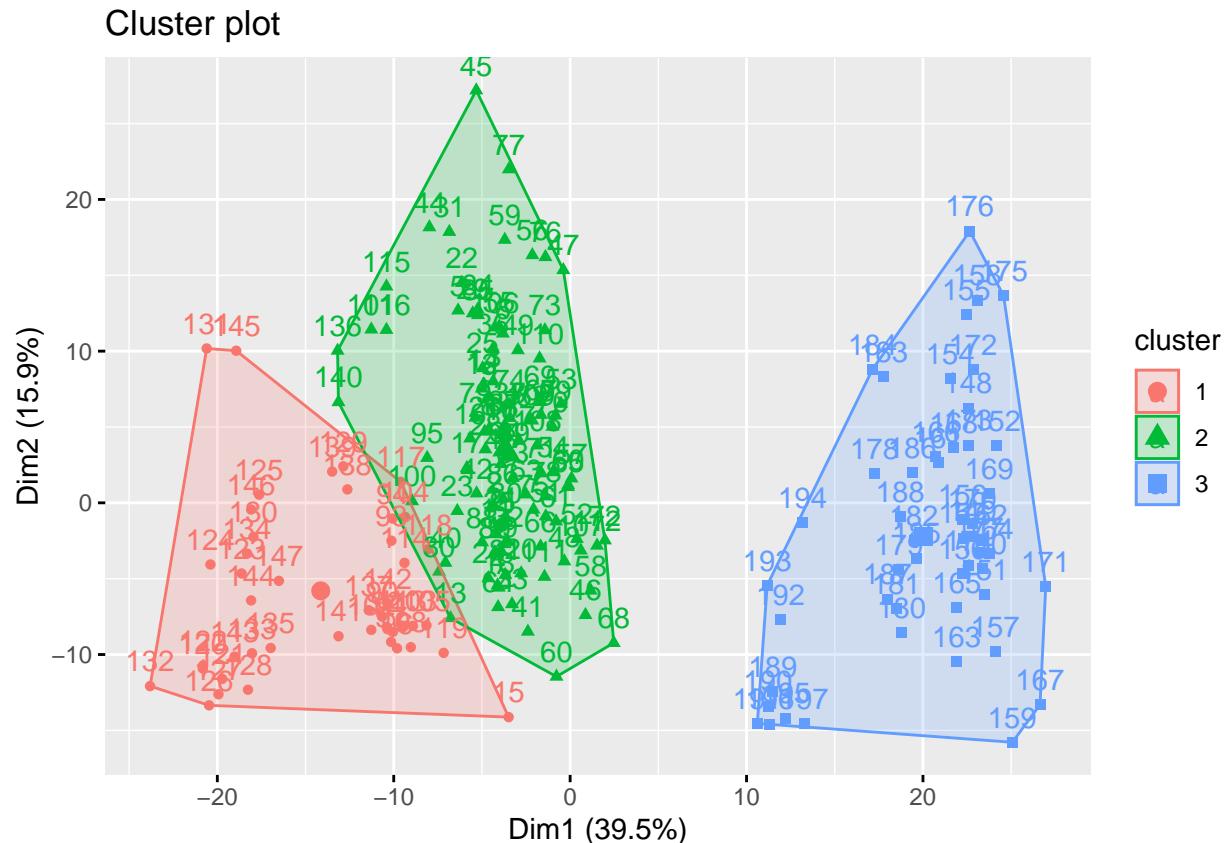
```

##      ZSNU.H.ADC ZSP.H.ADC GLNU_norm.H.ADC ZSNU_norm.H.ADC GLVAR_area.H.ADC
## 1 -0.03811053 -0.9997149   -1.26118455    -0.8740728    -0.3962385
## 2 -0.23482238 -0.1850766     0.05953909    -0.2387489    -0.4428720
## 3  0.51727138  1.2610069     0.98719188    1.2610069    1.2610062
##      ZSVAR.H.ADC Entropy_area.H.ADC Max_cooc.W.ADC Average_cooc.W.ADC
## 1 -0.87026837      -0.6180253   -1.2235870    -0.3007142
## 2 -0.02620128      -0.3481281   0.1290821    -0.3723147
## 3  0.81981081      1.2610062   0.8108473    1.0315968
##      Variance_cooc.W.ADC DAVE_cooc.W.ADC DVAR_cooc.W.ADC DENT_cooc.W.ADC
## 1      -0.57415096   -0.6388969   -0.61163767   -0.7149309
## 2      -0.08008876   -0.2961704   -0.09076978   -0.3067316
## 3      0.67023569   1.1723403   0.72522689   1.2610062
##      SAVE_cooc.W.ADC SVAR_cooc.W.ADC SENT_cooc.W.ADC ASM_cooc.W.ADC
## 1      -0.3121548   -0.52230929   -0.3572574   -1.2193996
## 2      -0.3680932   -0.07792817   -0.3284037   0.1276739
## 3      1.0329682   0.62016420   0.9908981   0.8100633
##      Contrast_cooc.W.ADC Dissimilarity_cooc.W.ADC Inv_diff_cooc.W.ADC
## 1      -0.5852988   -0.6388969   -1.0941138
## 2      -0.1102574   -0.2961704   -0.1119249
## 3      0.7421931   1.1723403   1.1933853
##      Inv_diff_norm_cooc.W.ADC IDM_cooc.W.ADC IDM_norm_cooc.W.ADC
## 1      -1.0332091   -1.15194943   -1.184432
## 2      -0.1707681   -0.09023132   -0.106168
## 3      1.2610062   1.19959202   1.261006
##      Inv_var_cooc.W.ADC Correlation_cooc.W.ADC Autocorrelation_cooc.W.ADC
## 1      -1.13055941   -0.6715404   -0.2375357
## 2      -0.09551775   -0.2088642   -0.2458585
## 3      1.19165885   1.0212158   0.7154998
##      Tendency_cooc.W.ADC Shade_cooc.W.ADC Prominence_cooc.W.ADC IC1_d.W.ADC
## 1      -0.52230929   -0.01899192   -0.4123323 -0.09228064
## 2      -0.07792817   -0.08233801   0.0284408  0.32940186
## 3      0.62016420   0.18632920   0.3042644 -0.59736087
##      IC2_d.W.ADC Coarseness_vdif.W.ADC Contrast_vdif.W.ADC Busyness_vdif.W.ADC
## 1      -0.8163227   -1.2320377   -0.67799661   -1.09537673
## 2      -0.2634185   0.1694735   -0.03596539   -0.01152585
## 3      1.2610062   0.7350778   0.67072573   0.98767477
##      Complexity_vdif.W.ADC Strength_vdif.W.ADC SRE_align.W.ADC LRE_align.W.ADC
## 1      -0.2915629   -0.55696810   -1.29436439   -1.1596097
## 2      -0.1148090   -0.04369006   -0.05920658   -0.1167717
## 3      0.4930819   0.58013345   1.26100621   1.2610062
##      GLNU_align.W.ADC RLNU_align.W.ADC RP_align.W.ADC LGRE_align.W.ADC
## 1      0.02983217   -0.03895424   -1.29131932   -1.2373352
## 2      -0.28927950   -0.22823909   -0.06050738   0.1438929
## 3      0.56966346   0.50445226   1.26100621   0.7924356
##      HGRE_align.W.ADC LGSRE_align.W.ADC HGSRE_align.W.ADC LGHRE_align.W.ADC
## 1      -0.2676759   -1.2366483   -0.2703353   -1.2383055
## 2      -0.2417845   0.1424456   -0.2405162   0.1510334
## 3      0.7336310   0.7948126   0.7333584   0.7785801
##      HGLRE_align.W.ADC GLNU_norm_align.W.ADC RLNU_norm_align.W.ADC
## 1      -0.2695919   -1.2413161   -1.26346860
## 2      -0.2442399   0.0744557   -0.07240495
## 3      0.7403751   0.9389794   1.26100657
##      GLVAR_align.W.ADC RLVAR_align.W.ADC Entropy_align.W.ADC SZSE.W.ADC
## 1      -0.57962404   -1.22478921   -0.4229567 -1.21016596

```

`fviz_cluster()` will perform principal component analysis (PCA) and plot the data points according to the first three principal components that explain the majority of variance

```
fviz_cluster(k3, data = df)
```



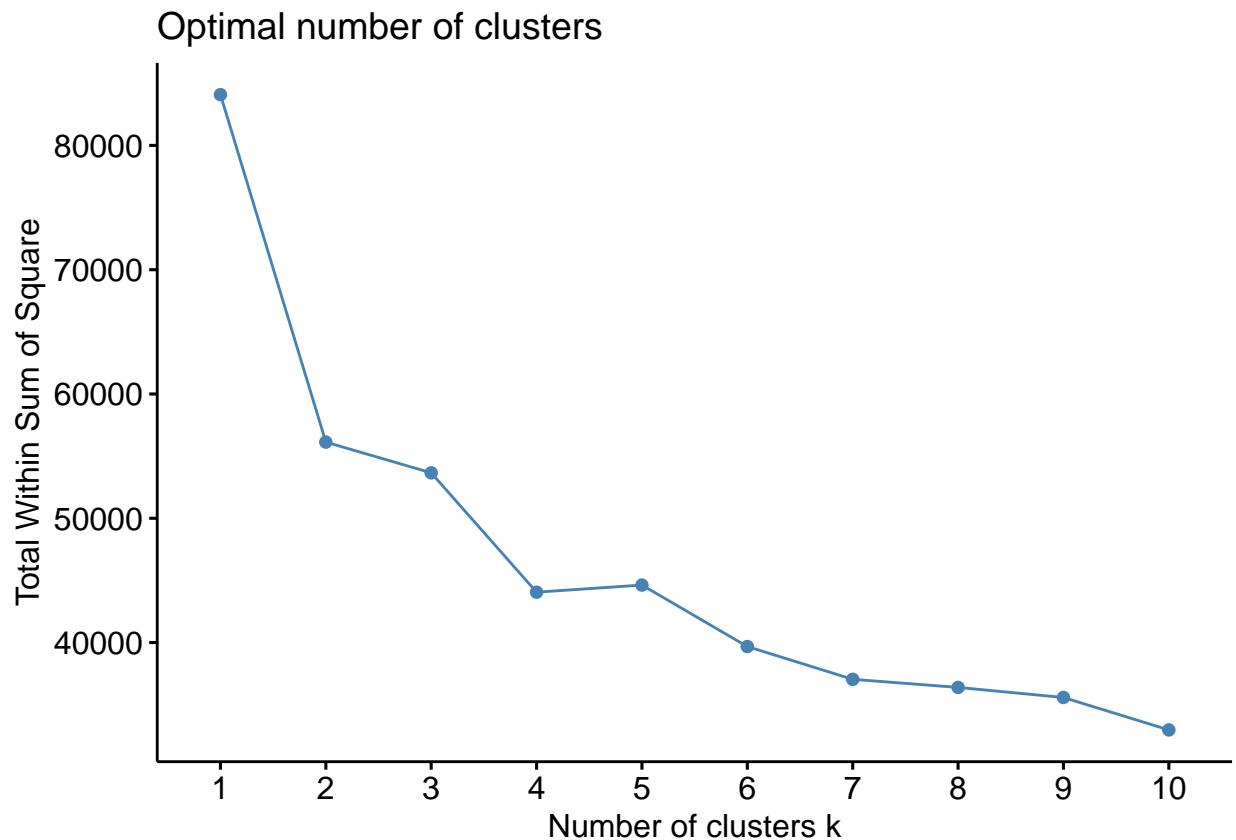
## Determining Optimal Clusters

In the elbow method, the results suggest that 2 is the optimal number of clusters as it appears to be the bend in the knee or elbow.

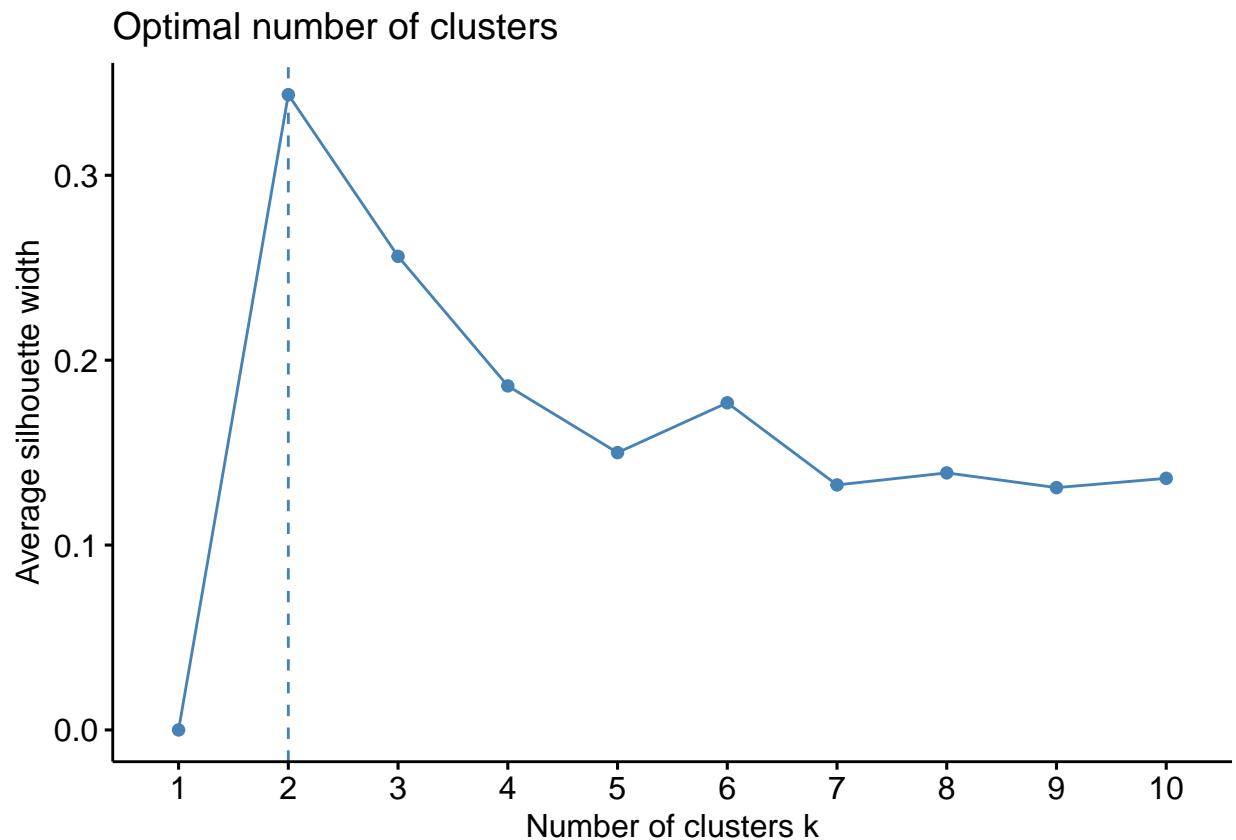
In the average silhouette method suggests that 2 clusters maximize the average silhouette values with 6 clusters coming in as second optimal number of clusters.

In the gap statistic method which suggests 2 clusters as the optimal number of clusters.

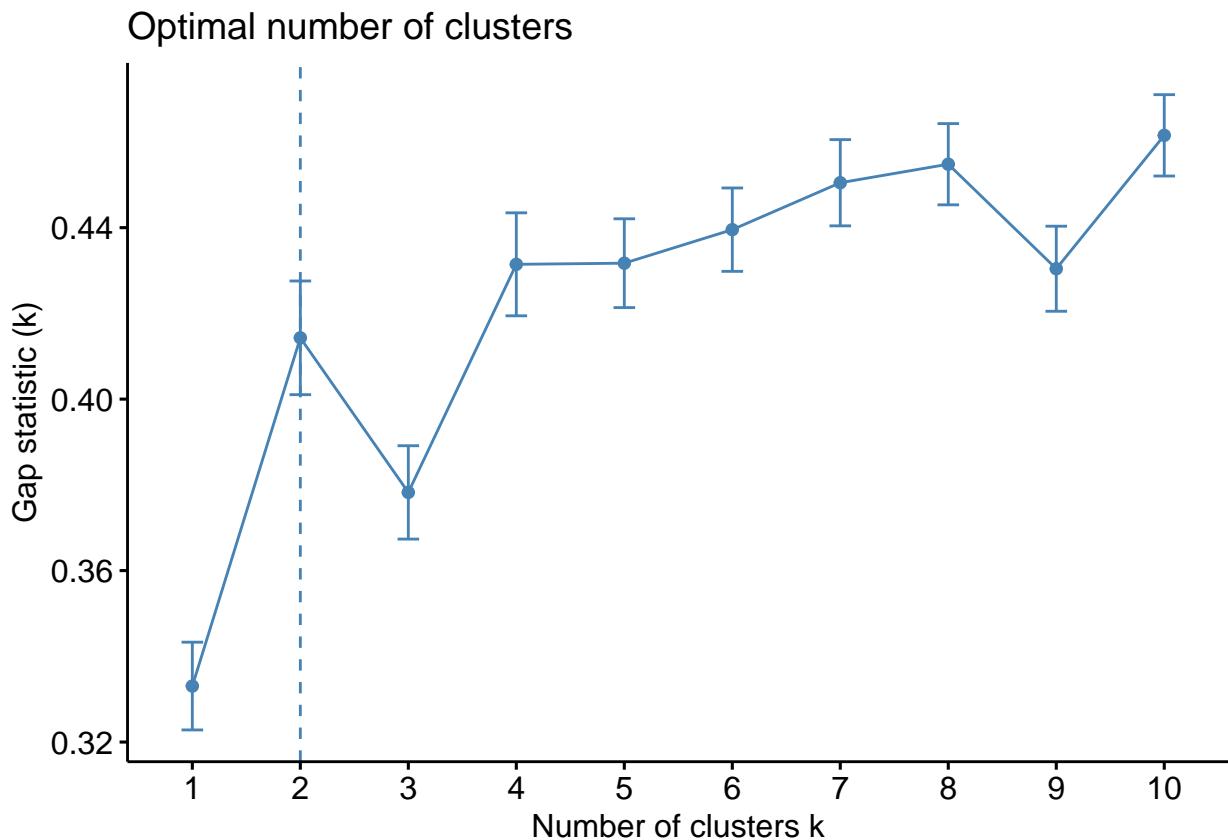
```
fviz_nbclust(df, kmeans, method = "wss")
```



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



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

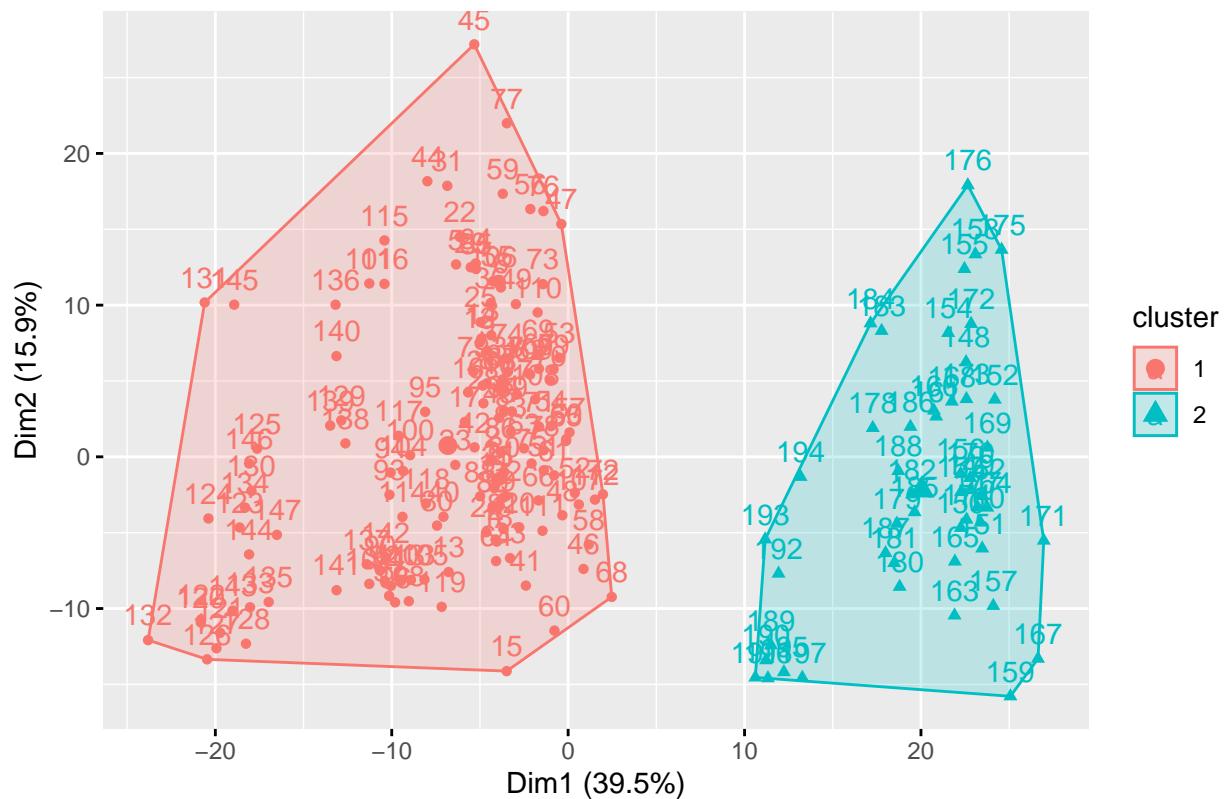


Final analysis, extract and plot the results using 2 clusters

With most of these approaches suggesting 2 as the number of optimal clusters, we perform the final analysis and extract the results using 2 clusters

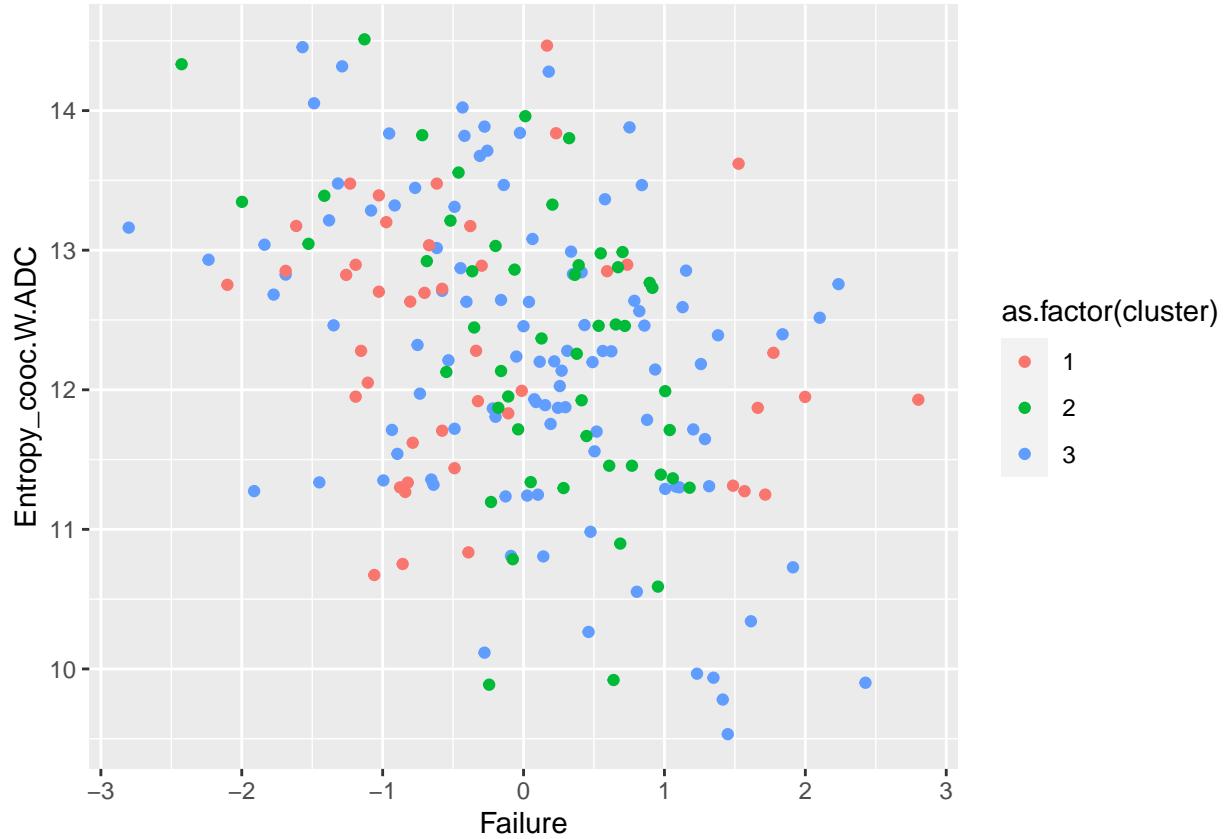
```
final <- kmeans(df, centers = 2, iter.max = 100, nstart = 100)
fviz_cluster(kmeans(df, centers = 2, iter.max = 100, nstart = 100), data = df)
```

Cluster plot



### Visualize clusters using original variables

```
clusters <- kmeans(df, centers = 3, iter.max = 100, nstart = 100)
radiomics <- radiomics |> mutate(cluster = clusters$cluster)
radiomics |> ggplot(aes(x = Failure, y = Entropy_cooc.W.ADC, col = as.factor(cluster))) + geom_point()
```



## Heirarchical Clustering

Hierarchical clustering is an alternative approach to k-means clustering for identifying groups in the dataset. Hierarchical clustering has an added advantage over K-means clustering in that it results in an attractive tree-based representation of the observations, called a dendrogram.

## Scaling/standardizing the data

```
df <- radiomics %>%
  select_if(is.numeric) %>% # select numeric columns
  select(-Failure.binary) %>% # remove target column
  mutate_all(as.double) %>% # coerce to double type
  scale()
```

## For Reproducibility

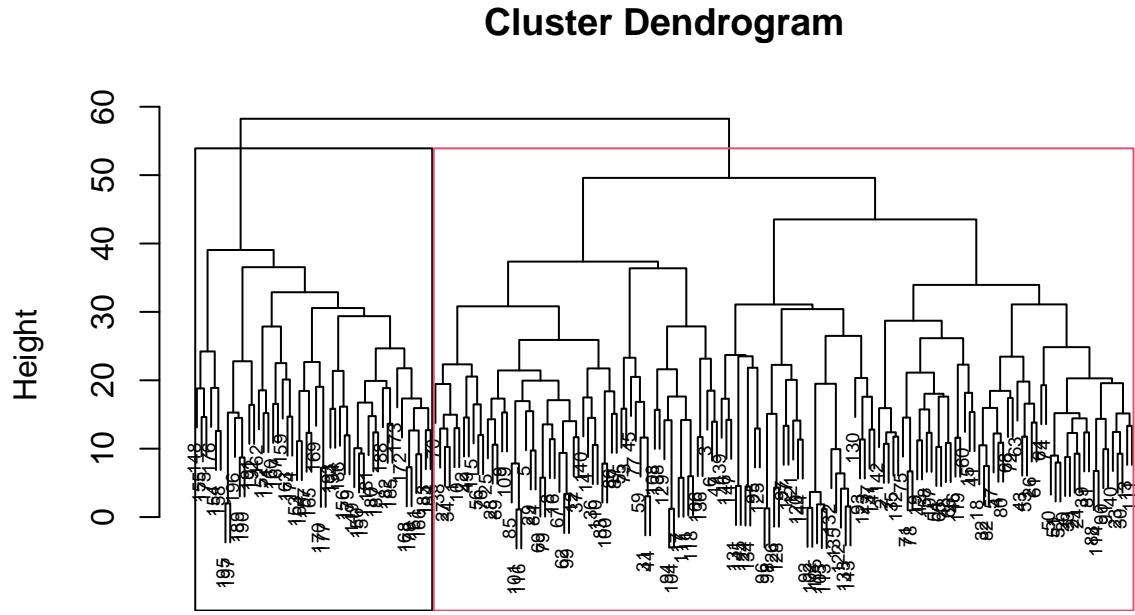
```
set.seed(123)
```

We compute the dissimilarity values with `dist()` and then feed these values into `hclust()`.

```
d <- dist(df, 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)
```



```
d
hclust (*, "complete")
```

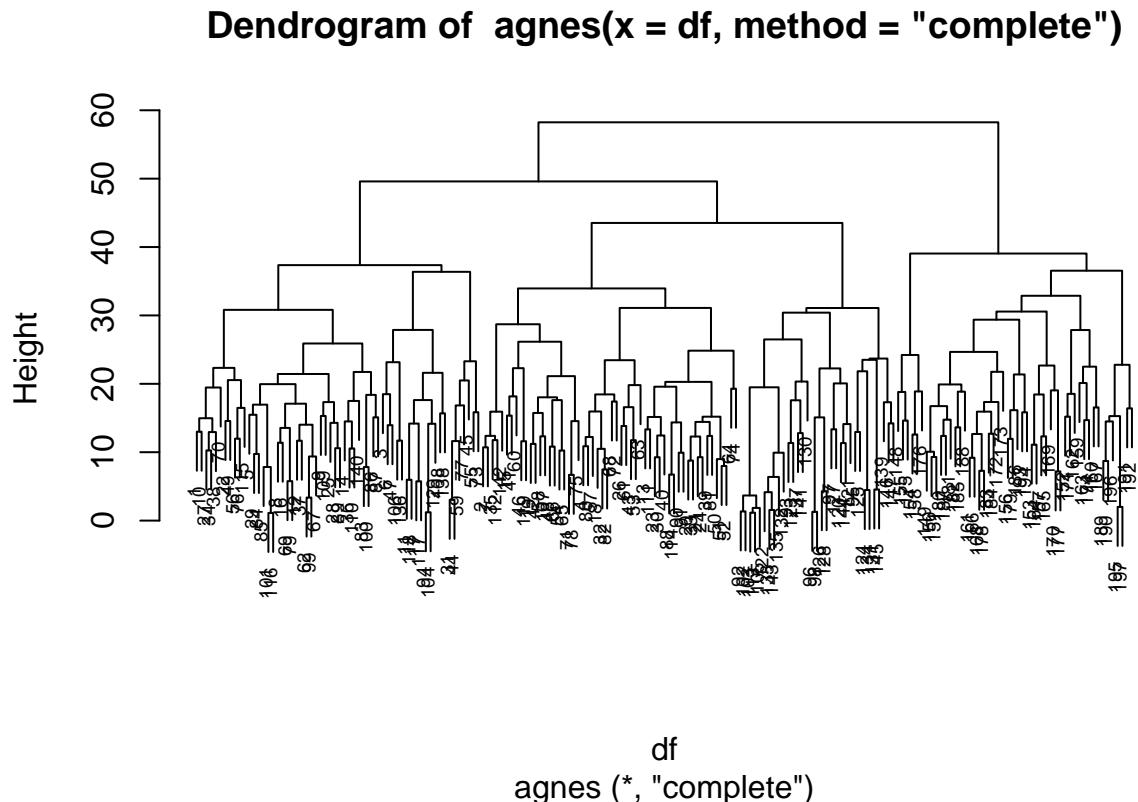
### Compute with Agnes

Using Agnes function we can get the agglomerative coefficient, which measures the amount of clustering structure found (values closer to 1 suggest strong clustering structure). Based on the result, 0.8072963, this value is closer to 1 which may suggest strong clustering structure.

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

## [1] 0.8072963

```
pltree(hc2, cex = 0.6)
```



Compute divisive hierarchical clustering using Diana

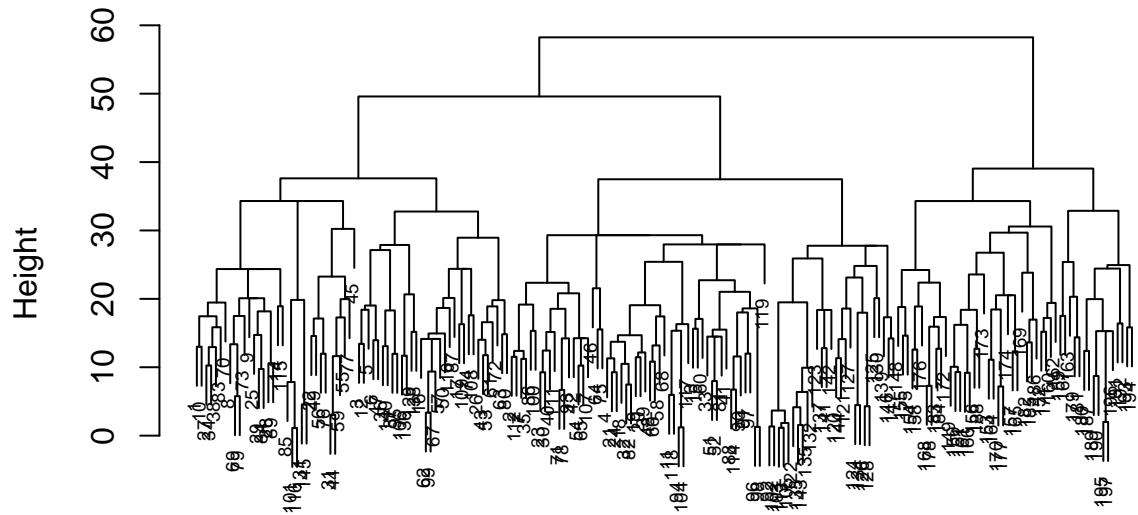
The divisive coefficient or amount of clustering structure found shows 0.7915983.

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

## [1] 0.7915983

```
pltree(hc4, cex = 0.6)
```

## Dendrogram of diana(x = df)



df  
diana (\*, "NA")

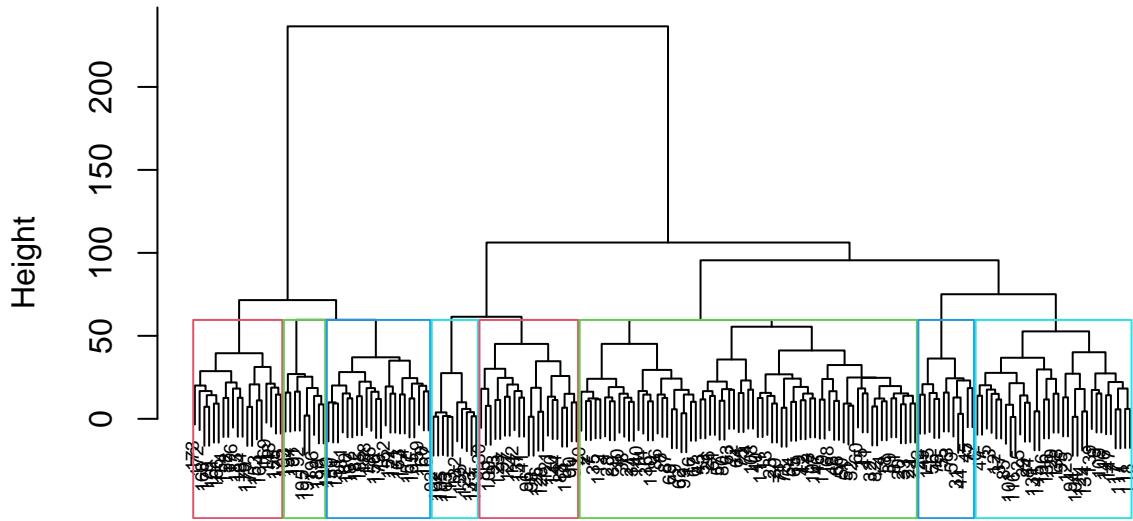
### Ward's method

```
hc5 <- hclust(d, method = "ward.D2" )  
sub_grp <- cutree(hc5, k = 8)  
table(sub_grp)
```

```
## sub_grp  
## 1 2 3 4 5 6 7 8  
## 71 33 12 21 10 19 22 9
```

```
plot(hc5, cex = 0.6)  
rect.hclust(hc5, k = 8, border = 2:5)
```

## Cluster Dendrogram



d  
hclust (\*, "ward.D2")

### Determining Optimal Clusters

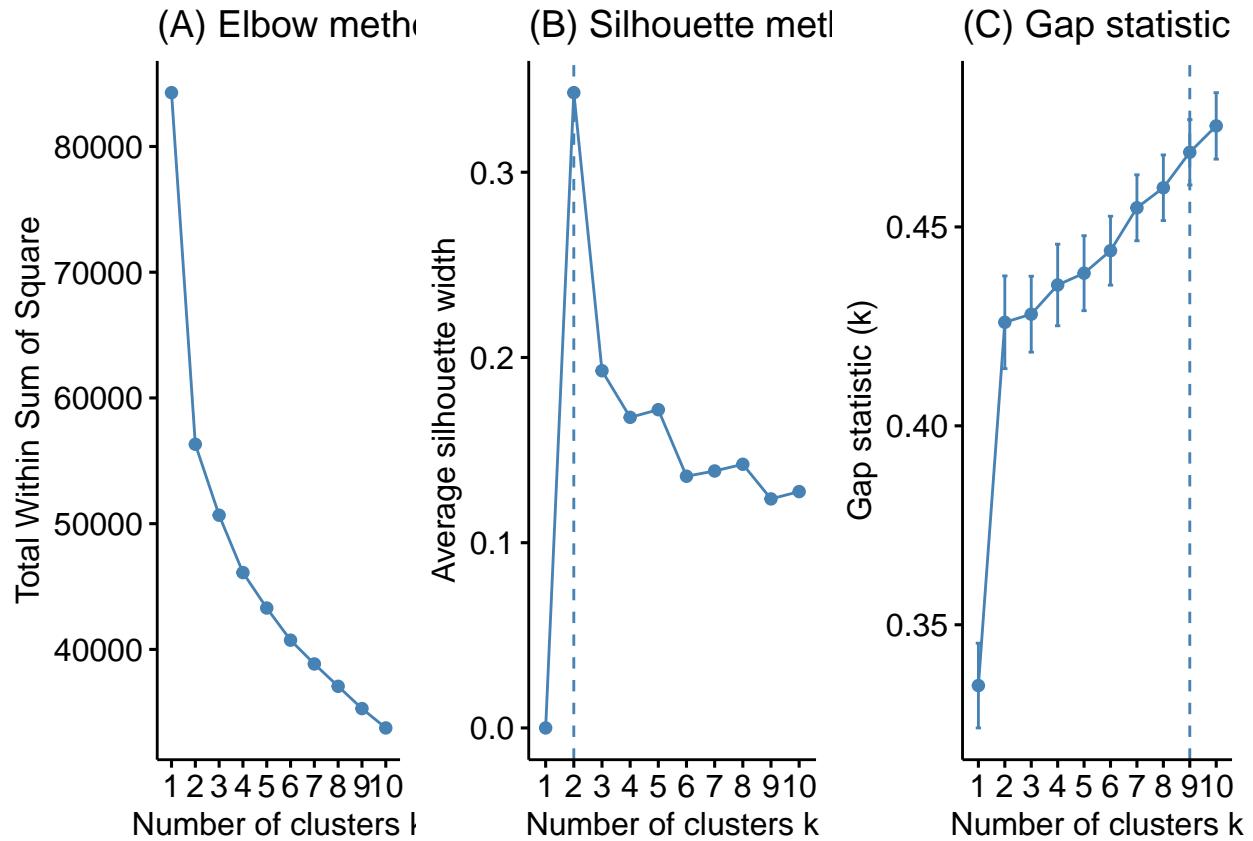
In the elbow method, the results suggest that 2 is the optimal number of clusters as it appears to be the bend in the knee or elbow.

In the average silhouette method suggests that 2 clusters maximize the average silhouette values with 5 clusters coming in as second optimal number of clusters.

In the gap statistic method which suggests 9 clusters as the optimal number of clusters.

```
p1 <- fviz_nbclust(df, FUN = hcut, method = "wss",
  k.max = 10) +
  ggtitle("(A) Elbow method")
p2 <- fviz_nbclust(df, FUN = hcut, method = "silhouette",
  k.max = 10) +
  ggtitle("(B) Silhouette method")
p3 <- fviz_nbclust(df, FUN = hcut, method = "gap_stat",
  k.max = 10) +
  ggtitle("(C) Gap statistic")

gridExtra::grid.arrange(p1, p2, p3, nrow = 1)
```



## Model-Based

Based from our result, we obtained a negative log-likelihood, negative BIC and ICL which means that a negative

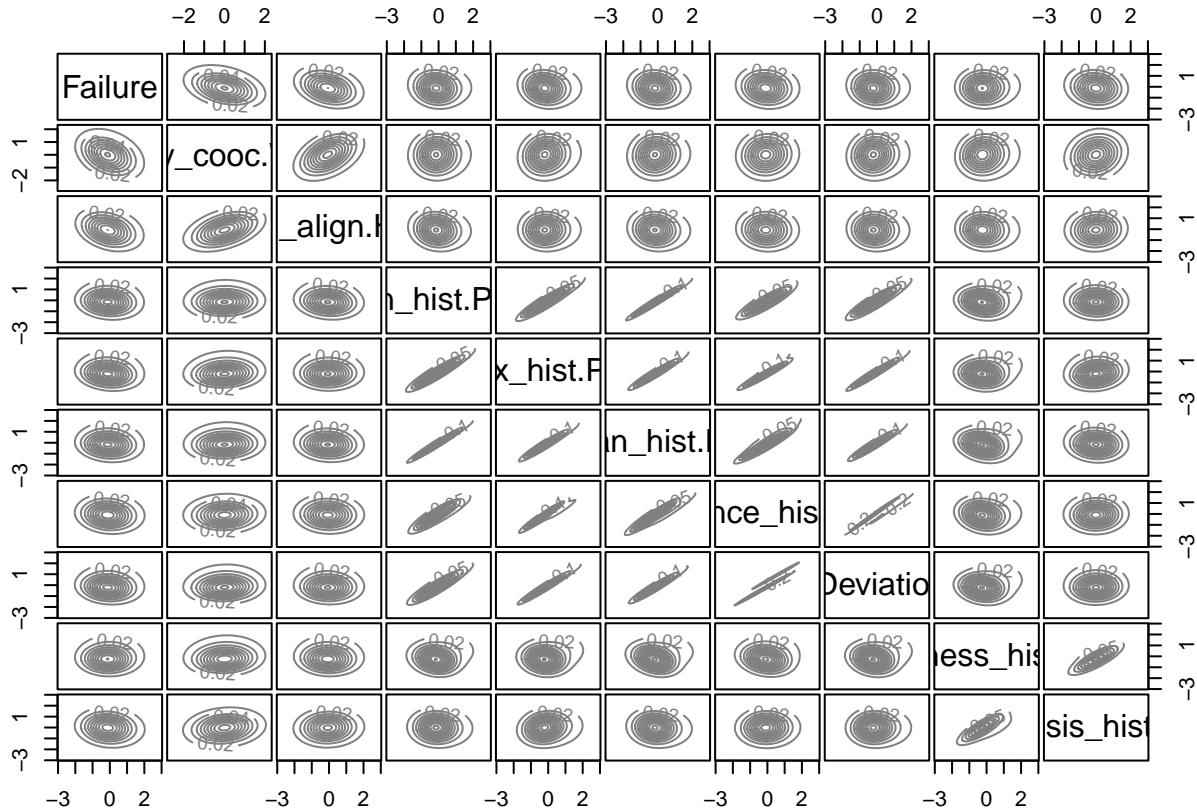
number is lower in magnitude and is thus the “better” model.

```
model3 <- Mclust(df[,1:10], G=3)
summary(model3)
```

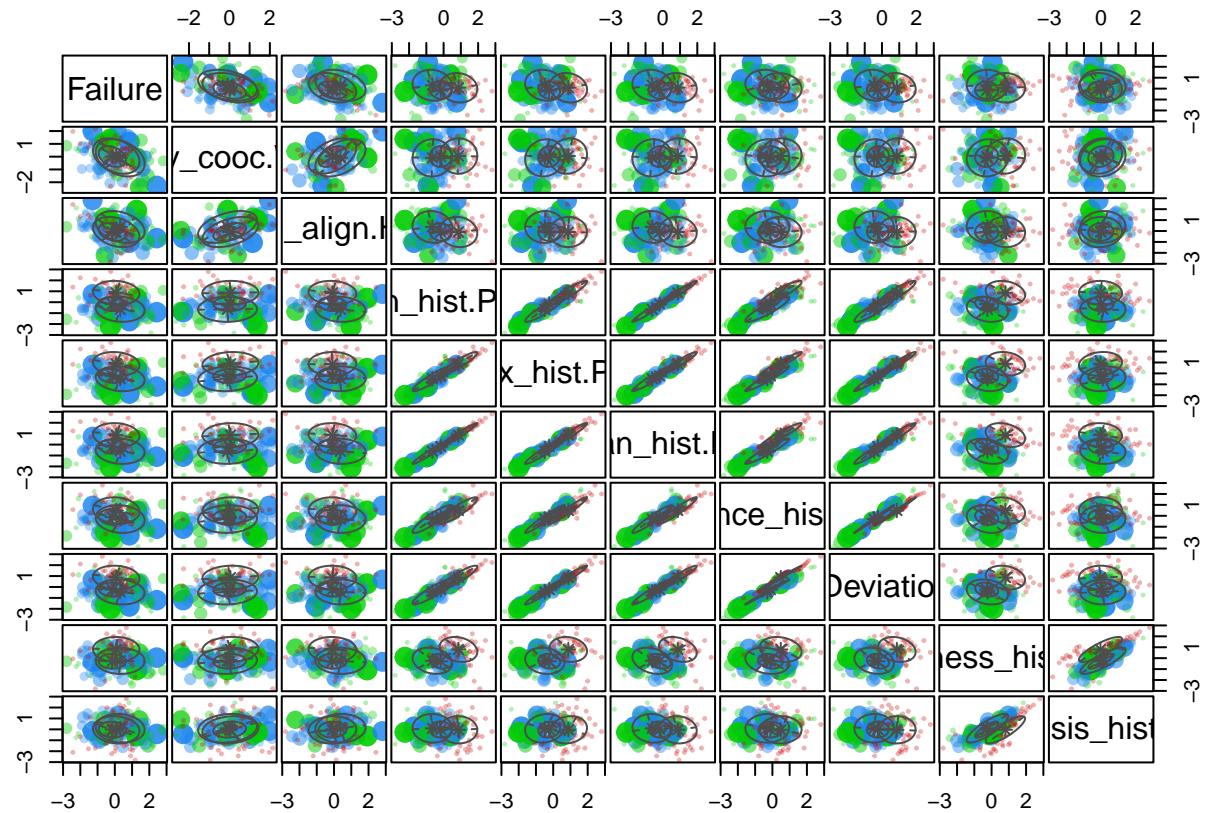
```
## -----
## Gaussian finite mixture model fitted by EM algorithm
## -----
## 
## Mclust VEE (ellipsoidal, equal shape and orientation) model with 3 components:
## 
##   log-likelihood   n  df        BIC       ICL
##             -1074.583 197 89 -2619.371 -2638.94
## 
## Clustering table:
##   1 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

## Plot results

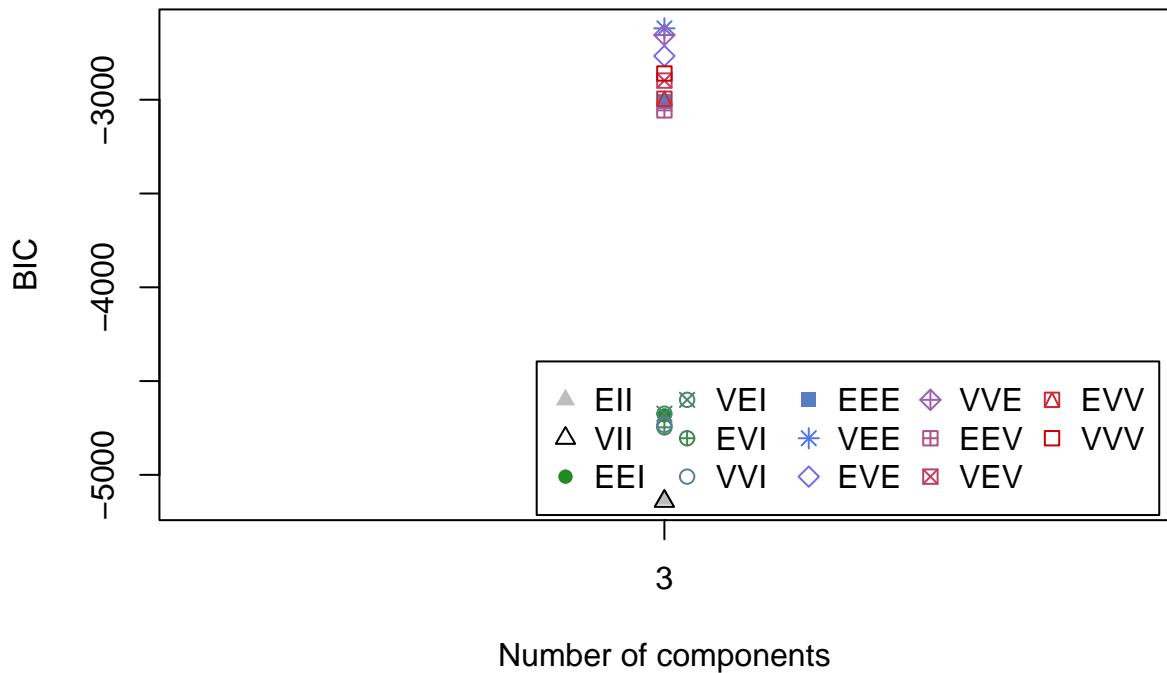
```
plot(model3, what = "density")
```



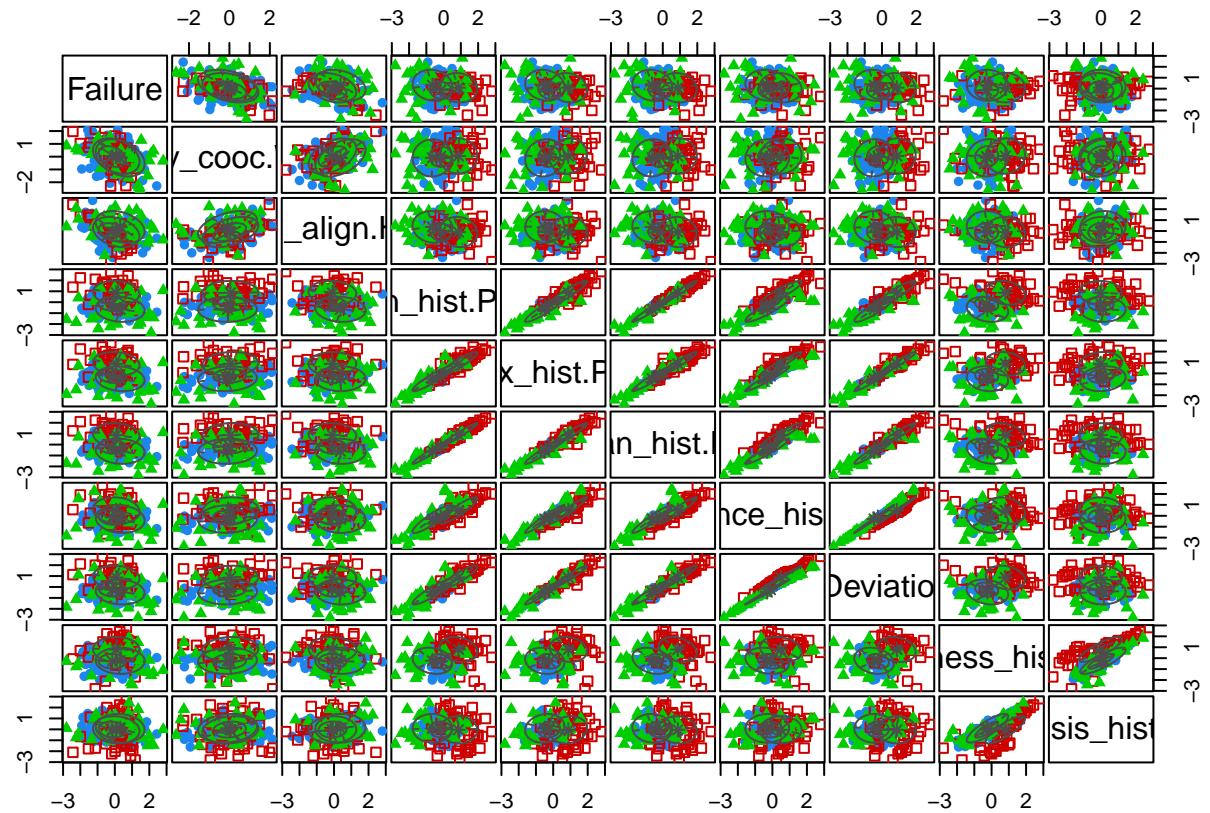
```
plot(model3, what = "uncertainty")
```



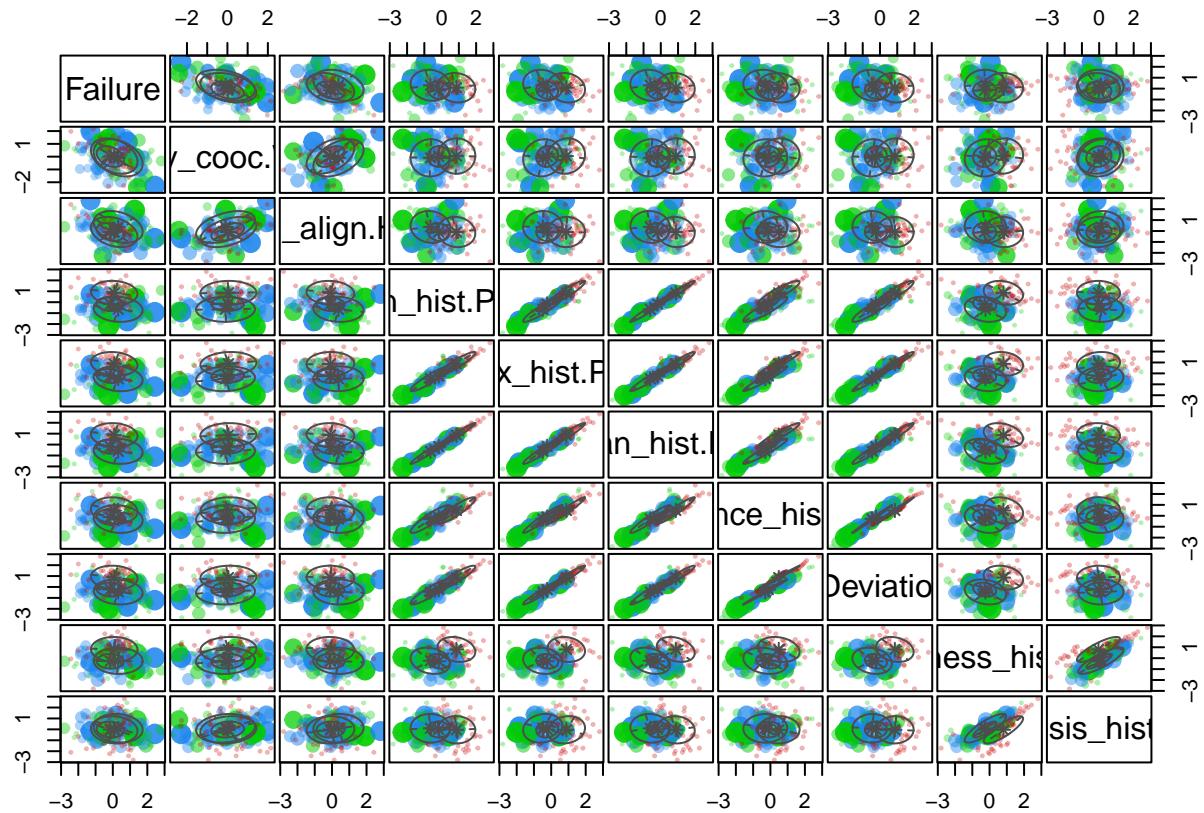
```
legend_args <- list(x = "bottomright", ncol = 5)
plot(model3, what = 'BIC', legendArgs = legend_args)
```



```
plot(model3, what = 'classification')
```



```
plot(model3, what = 'uncertainty')
```



```

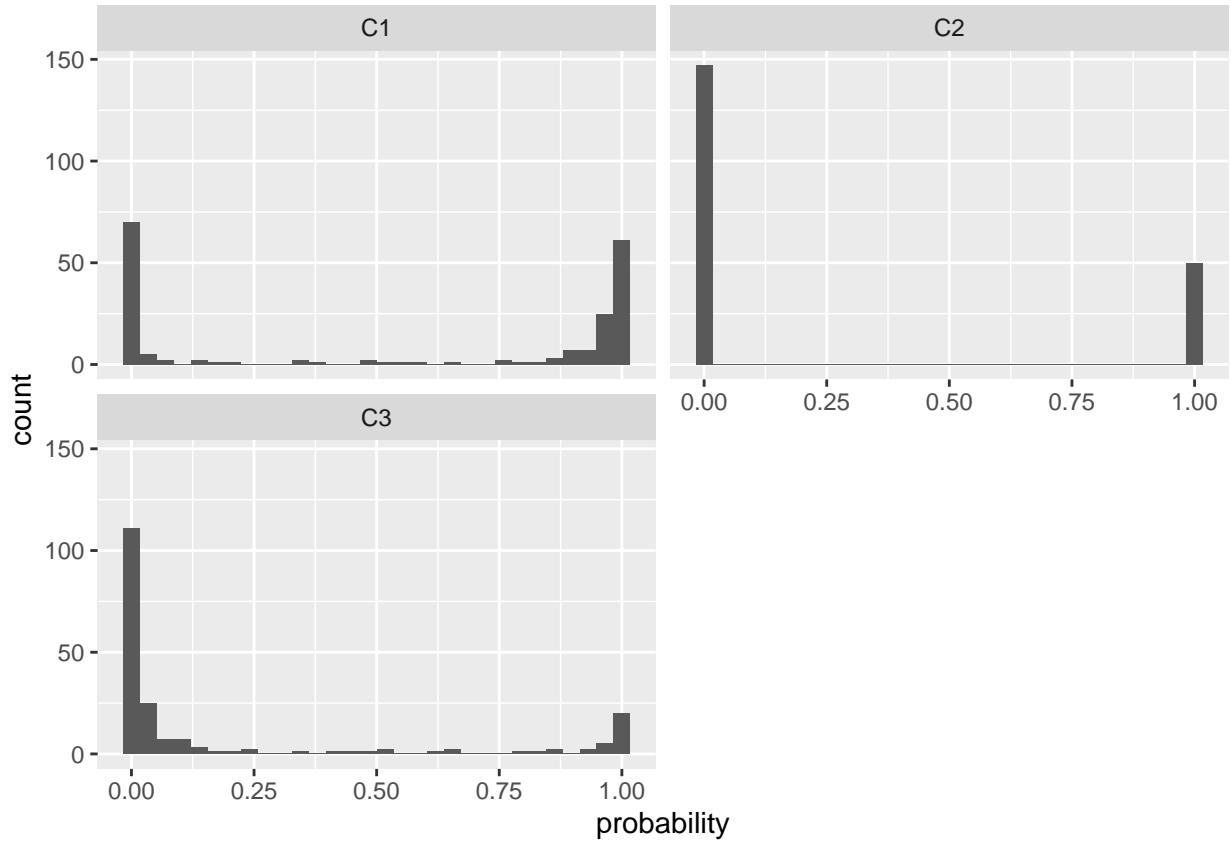
probabilities <- model3$z
colnames(probabilities) <- paste0('C', 1:3)

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

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

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

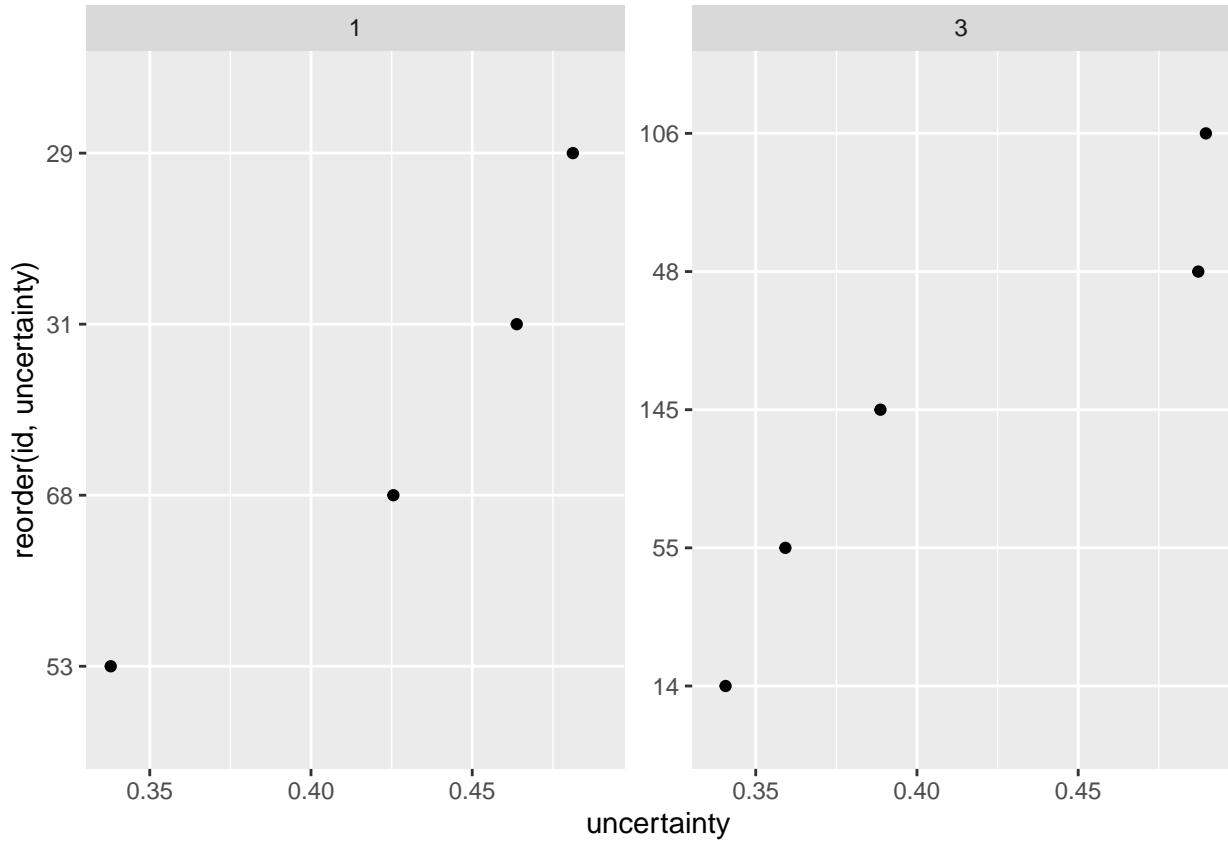
```



```

uncertainty <- data.frame(
  id = 1:nrow(df),
  cluster = model3$classification,
  uncertainty = model3$uncertainty
)
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 <- df %>%
  scale() %>%
  as.data.frame() %>%
  mutate(cluster = model3$classification) %>%
  filter(cluster == 2) %>%
  select(-cluster)

cluster2 %>%
  tidyverse::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)
  
```

