Breast Cancer Wisconsin Data Analysis

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2023-08-13

Libraries and Dataset

```
library(dplyr)
library(corrplot)
library(psych)
library(yacca)
library(REdaS)
library(ggplot2)
library(ltm)

data <- read.csv("~/Downloads/data.csv")
```

I will be applying Common Factor Analysis on the Breast Cancer Dataset -

Introduction

Determining dimensions of Breast Cancer using Common Factor Analysis (CFA)
First we will discover and visualize the data to gain insights then we will apply Common factor analysis (CFA) to determine which features effect Breast Cancer the most

The Dataset
The Breast Cancer (Wisconsin) Diagnosis dataset contains the diagnosis and a set of 30 features describing the characteristics of the cell nuclei present in the digitized image of a fine needle aspirate (FNA) of a breast mass.

Attribute Information:

1) ID number

2) Diagnosis (M = malignant, B = benign)

Ten real-valued features are computed for each cell nucleus:

a) radius (mean of distances from center to points on the perimeter)

b) texture (standard deviation of gray-scale values)

c) perimeter

d) area

e) smoothness (local variation in radius lengths)

f) compactness (perimeter^2 / area - 1.0)

g) concavity (severity of concave portions of the contour)

h) concave points (number of concave portions of the contour)

i) symmetry

j) fractal dimension ("coastline approximation" - 1)

The mean, standard error and "worst" or largest (mean of the three largest values) of these features were computed for each image, resulting in 30 features. For instance, field 3 is Mean Radius, field 13 is Radius SE, field 23 is Worst Radius.
All feature values are re-coded with four significant digits [1]

Fine Needle Aspiration of the Breast
According to the American Cancer Society website, during a fine needle aspiration (FNA), a small amount of breast tissue or fluid is removed from a suspicious area with a thin, hollow needle and checked for cancer cells. This type of biopsy is sometimes an option if other tests show you might have breast cancer (although a core needle biopsy is often preferred) [2]

Data Cleaning and Inspection

```
#Checking Sample Size and Number of Variables
dim(data)
```

```
## [1] 569  33
```

```
#569-Sample Size and 34 variables
```

```
#Showing head of the dataset
head(data, 3)
```

```
##         id diagnosis radius_mean texture_mean perimeter_mean area_mean
## 1   842302         M       17.99        10.38          122.8      1001
## 2   842517         M       20.57        17.77          132.9      1326
## 3 84300903         M       19.69        21.25          130.0      1203
##   smoothness_mean compactness_mean concavity_mean concave.points_mean
## 1         0.11840          0.27760         0.3001             0.14710
## 2         0.08474          0.07864         0.0869             0.07017
## 3         0.10960          0.15990         0.1974             0.12790
##   symmetry_mean fractal_dimension_mean radius_se texture_se perimeter_se
```

```
## 1        0.2419                0.07871    1.0950     0.9053        8.589
## 2        0.1812                0.05667    0.5435     0.7339        3.398
## 3        0.2069                0.05999    0.7456     0.7869        4.585
##   area_se smoothness_se compactness_se concavity_se concave.points_se
## 1  153.40      0.006399        0.04904      0.05373           0.01587
## 2   74.08      0.005225        0.01308      0.01860           0.01340
## 3   94.03      0.006150        0.04006      0.03832           0.02058
##   symmetry_se fractal_dimension_se radius_worst texture_worst perimeter_worst
## 1     0.03003             0.006193        25.38         17.33           184.6
## 2     0.01389             0.003532        24.99         23.41           158.8
## 3     0.02250             0.004571        23.57         25.53           152.5
##   area_worst smoothness_worst compactness_worst concavity_worst
## 1       2019           0.1622            0.6656          0.7119
## 2       1956           0.1238            0.1866          0.2416
## 3       1709           0.1444            0.4245          0.4504
##   concave.points_worst symmetry_worst fractal_dimension_worst  X
## 1               0.2654         0.4601                 0.11890 NA
## 2               0.1860         0.2750                 0.08902 NA
## 3               0.2430         0.3613                 0.08758 NA
```

```
#Showing summary of the dataset
summary(data)
```

```
##        id              diagnosis          radius_mean      texture_mean
##  Min.   :     8670   Length:569         Min.   : 6.981   Min.   : 9.71
##  1st Qu.:   869218   Class :character   1st Qu.:11.700   1st Qu.:16.17
##  Median :   906024   Mode  :character   Median :13.370   Median :18.84
##  Mean   : 30371831                      Mean   :14.127   Mean   :19.29
##  3rd Qu.:  8813129                      3rd Qu.:15.780   3rd Qu.:21.80
##  Max.   :911320502                      Max.   :28.110   Max.   :39.28
##  perimeter_mean     area_mean      smoothness_mean   compactness_mean
##  Min.   : 43.79   Min.   : 143.5   Min.   :0.05263   Min.   :0.01938
##  1st Qu.: 75.17   1st Qu.: 420.3   1st Qu.:0.08637   1st Qu.:0.06492
##  Median : 86.24   Median : 551.1   Median :0.09587   Median :0.09263
##  Mean   : 91.97   Mean   : 654.9   Mean   :0.09636   Mean   :0.10434
##  3rd Qu.:104.10   3rd Qu.: 782.7   3rd Qu.:0.10530   3rd Qu.:0.13040
##  Max.   :188.50   Max.   :2501.0   Max.   :0.16340   Max.   :0.34540
##  concavity_mean    concave.points_mean symmetry_mean    fractal_dimension_mean
##  Min.   :0.00000   Min.   :0.00000     Min.   :0.1060   Min.   :0.04996
##  1st Qu.:0.02956   1st Qu.:0.02031     1st Qu.:0.1619   1st Qu.:0.05770
##  Median :0.06154   Median :0.03350     Median :0.1792   Median :0.06154
##  Mean   :0.08880   Mean   :0.04892     Mean   :0.1812   Mean   :0.06280
##  3rd Qu.:0.13070   3rd Qu.:0.07400     3rd Qu.:0.1957   3rd Qu.:0.06612
##  Max.   :0.42680   Max.   :0.20120     Max.   :0.3040   Max.   :0.09744
##    radius_se        texture_se      perimeter_se       area_se
##  Min.   :0.1115   Min.   :0.3602   Min.   : 0.757   Min.   :  6.802
##  1st Qu.:0.2324   1st Qu.:0.8339   1st Qu.: 1.606   1st Qu.: 17.850
##  Median :0.3242   Median :1.1080   Median : 2.287   Median : 24.530
##  Mean   :0.4052   Mean   :1.2169   Mean   : 2.866   Mean   : 40.337
##  3rd Qu.:0.4789   3rd Qu.:1.4740   3rd Qu.: 3.357   3rd Qu.: 45.190
##  Max.   :2.8730   Max.   :4.8850   Max.   :21.980   Max.   :542.200
##  smoothness_se      compactness_se      concavity_se     concave.points_se
##  Min.   :0.001713   Min.   :0.002252   Min.   :0.00000   Min.   :0.000000
##  1st Qu.:0.005169   1st Qu.:0.013080   1st Qu.:0.01509   1st Qu.:0.007638
```

```
##  Median :0.006380   Median :0.020450   Median :0.02589   Median :0.010930
##  Mean   :0.007041   Mean   :0.025478   Mean   :0.03189   Mean   :0.011796
##  3rd Qu.:0.008146   3rd Qu.:0.032450   3rd Qu.:0.04205   3rd Qu.:0.014710
##  Max.   :0.031130   Max.   :0.135400   Max.   :0.39600   Max.   :0.052790
##   symmetry_se       fractal_dimension_se  radius_worst   texture_worst
##  Min.   :0.007882   Min.   :0.0008948    Min.   : 7.93   Min.   :12.02
##  1st Qu.:0.015160   1st Qu.:0.0022480    1st Qu.:13.01   1st Qu.:21.08
##  Median :0.018730   Median :0.0031870    Median :14.97   Median :25.41
##  Mean   :0.020542   Mean   :0.0037949    Mean   :16.27   Mean   :25.68
##  3rd Qu.:0.023480   3rd Qu.:0.0045580    3rd Qu.:18.79   3rd Qu.:29.72
##  Max.   :0.078950   Max.   :0.0298400    Max.   :36.04   Max.   :49.54
##  perimeter_worst    area_worst     smoothness_worst  compactness_worst
##  Min.   : 50.41   Min.   : 185.2   Min.   :0.07117   Min.   :0.02729
##  1st Qu.: 84.11   1st Qu.: 515.3   1st Qu.:0.11660   1st Qu.:0.14720
##  Median : 97.66   Median : 686.5   Median :0.13130   Median :0.21190
##  Mean   :107.26   Mean   : 880.6   Mean   :0.13237   Mean   :0.25427
##  3rd Qu.:125.40   3rd Qu.:1084.0   3rd Qu.:0.14600   3rd Qu.:0.33910
##  Max.   :251.20   Max.   :4254.0   Max.   :0.22260   Max.   :1.05800
##  concavity_worst  concave.points_worst symmetry_worst   fractal_dimension_worst
##  Min.   :0.0000   Min.   :0.00000      Min.   :0.1565   Min.   :0.05504
##  1st Qu.:0.1145   1st Qu.:0.06493      1st Qu.:0.2504   1st Qu.:0.07146
##  Median :0.2267   Median :0.09993      Median :0.2822   Median :0.08004
##  Mean   :0.2722   Mean   :0.11461      Mean   :0.2901   Mean   :0.08395
##  3rd Qu.:0.3829   3rd Qu.:0.16140      3rd Qu.:0.3179   3rd Qu.:0.09208
##  Max.   :1.2520   Max.   :0.29100      Max.   :0.6638   Max.   :0.20750
##     X
##  Mode:logical
##  NA's:569
##
##
##
##
```

```
#Showing structure of the dataset
str(data)
```

```
## 'data.frame':    569 obs. of  33 variables:
##  $ id                      : int  842302 842517 84300903 84348301 84358402 843786 844359 84458202 844
##  $ diagnosis               : chr  "M" "M" "M" "M" ...
##  $ radius_mean             : num  18 20.6 19.7 11.4 20.3 ...
##  $ texture_mean            : num  10.4 17.8 21.2 20.4 14.3 ...
##  $ perimeter_mean          : num  122.8 132.9 130 77.6 135.1 ...
##  $ area_mean               : num  1001 1326 1203 386 1297 ...
##  $ smoothness_mean         : num  0.1184 0.0847 0.1096 0.1425 0.1003 ...
##  $ compactness_mean        : num  0.2776 0.0786 0.1599 0.2839 0.1328 ...
##  $ concavity_mean          : num  0.3001 0.0869 0.1974 0.2414 0.198 ...
##  $ concave.points_mean     : num  0.1471 0.0702 0.1279 0.1052 0.1043 ...
##  $ symmetry_mean           : num  0.242 0.181 0.207 0.26 0.181 ...
##  $ fractal_dimension_mean  : num  0.0787 0.0567 0.06 0.0974 0.0588 ...
##  $ radius_se               : num  1.095 0.543 0.746 0.496 0.757 ...
##  $ texture_se              : num  0.905 0.734 0.787 1.156 0.781 ...
##  $ perimeter_se            : num  8.59 3.4 4.58 3.44 5.44 ...
##  $ area_se                 : num  153.4 74.1 94 27.2 94.4 ...
##  $ smoothness_se           : num  0.0064 0.00522 0.00615 0.00911 0.01149 ...
```

```
##  $ compactness_se         : num  0.049 0.0131 0.0401 0.0746 0.0246 ...
##  $ concavity_se           : num  0.0537 0.0186 0.0383 0.0566 0.0569 ...
##  $ concave.points_se      : num  0.0159 0.0134 0.0206 0.0187 0.0188 ...
##  $ symmetry_se            : num  0.03 0.0139 0.0225 0.0596 0.0176 ...
##  $ fractal_dimension_se   : num  0.00619 0.00353 0.00457 0.00921 0.00511 ...
##  $ radius_worst           : num  25.4 25 23.6 14.9 22.5 ...
##  $ texture_worst          : num  17.3 23.4 25.5 26.5 16.7 ...
##  $ perimeter_worst        : num  184.6 158.8 152.5 98.9 152.2 ...
##  $ area_worst             : num  2019 1956 1709 568 1575 ...
##  $ smoothness_worst       : num  0.162 0.124 0.144 0.21 0.137 ...
##  $ compactness_worst      : num  0.666 0.187 0.424 0.866 0.205 ...
##  $ concavity_worst        : num  0.712 0.242 0.45 0.687 0.4 ...
##  $ concave.points_worst   : num  0.265 0.186 0.243 0.258 0.163 ...
##  $ symmetry_worst         : num  0.46 0.275 0.361 0.664 0.236 ...
##  $ fractal_dimension_worst: num  0.1189 0.089 0.0876 0.173 0.0768 ...
##  $ X                      : logi  NA NA NA NA NA NA ...
```

```r
#Checking for missing values
colSums(is.na(data))
```

```
##                      id               diagnosis             radius_mean
##                       0                       0                       0
##            texture_mean          perimeter_mean               area_mean
##                       0                       0                       0
##         smoothness_mean        compactness_mean          concavity_mean
##                       0                       0                       0
##     concave.points_mean          symmetry_mean  fractal_dimension_mean
##                       0                       0                       0
##               radius_se              texture_se            perimeter_se
##                       0                       0                       0
##                 area_se           smoothness_se          compactness_se
##                       0                       0                       0
##            concavity_se       concave.points_se             symmetry_se
##                       0                       0                       0
##    fractal_dimension_se            radius_worst           texture_worst
##                       0                       0                       0
##         perimeter_worst              area_worst        smoothness_worst
##                       0                       0                       0
##       compactness_worst         concavity_worst    concave.points_worst
##                       0                       0                       0
##          symmetry_worst fractal_dimension_worst                       X
##                       0                       0                     569
```

```r
#569 total missing values were found in X variable
```

```r
#Treating Missing Values

#Sub-setting out the X variable and saving in a new dataframe
data_clean <- data[,1:32]

#Checking if new data has any missing values
colSums(is.na(data_clean))
```

```
##                      id               diagnosis             radius_mean
##                       0                       0                       0
##            texture_mean          perimeter_mean               area_mean
##                       0                       0                       0
##         smoothness_mean        compactness_mean          concavity_mean
##                       0                       0                       0
##     concave.points_mean           symmetry_mean  fractal_dimension_mean
##                       0                       0                       0
##               radius_se              texture_se            perimeter_se
##                       0                       0                       0
##                 area_se           smoothness_se          compactness_se
##                       0                       0                       0
##            concavity_se       concave.points_se             symmetry_se
##                       0                       0                       0
##    fractal_dimension_se            radius_worst           texture_worst
##                       0                       0                       0
##         perimeter_worst              area_worst        smoothness_worst
##                       0                       0                       0
##       compactness_worst         concavity_worst    concave.points_worst
##                       0                       0                       0
##          symmetry_worst fractal_dimension_worst
##                       0                       0
```

```
#no missing values found
```

```
#Removing the ID column
wbcd <- data_clean[,2:32]

#converting the diagnosis variable into a factor
wbcd$diagnosis <- factor(ifelse(wbcd$diagnosis=='B',"Bening","Malignant"))

#now converting diagnosis as a double - 1 if Malignant and 0 if Benign
wbcd_n <- wbcd %>%
  mutate_at(vars(diagnosis), as.double) %>%
  mutate(diagnosis = diagnosis - 1)


#checking the structure of the new dataframe
str(wbcd_n)
```

```
## 'data.frame':    569 obs. of  31 variables:
##  $ diagnosis              : num  1 1 1 1 1 1 1 1 1 1 ...
##  $ radius_mean            : num  18 20.6 19.7 11.4 20.3 ...
##  $ texture_mean           : num  10.4 17.8 21.2 20.4 14.3 ...
##  $ perimeter_mean         : num  122.8 132.9 130 77.6 135.1 ...
##  $ area_mean              : num  1001 1326 1203 386 1297 ...
##  $ smoothness_mean        : num  0.1184 0.0847 0.1096 0.1425 0.1003 ...
##  $ compactness_mean       : num  0.2776 0.0786 0.1599 0.2839 0.1328 ...
##  $ concavity_mean         : num  0.3001 0.0869 0.1974 0.2414 0.198 ...
##  $ concave.points_mean    : num  0.1471 0.0702 0.1279 0.1052 0.1043 ...
##  $ symmetry_mean          : num  0.242 0.181 0.207 0.26 0.181 ...
##  $ fractal_dimension_mean : num  0.0787 0.0567 0.06 0.0974 0.0588 ...
##  $ radius_se              : num  1.095 0.543 0.746 0.496 0.757 ...
```

```
##  $ texture_se             : num  0.905 0.734 0.787 1.156 0.781 ...
##  $ perimeter_se           : num  8.59 3.4 4.58 3.44 5.44 ...
##  $ area_se                : num  153.4 74.1 94 27.2 94.4 ...
##  $ smoothness_se          : num  0.0064 0.00522 0.00615 0.00911 0.01149 ...
##  $ compactness_se         : num  0.049 0.0131 0.0401 0.0746 0.0246 ...
##  $ concavity_se           : num  0.0537 0.0186 0.0383 0.0566 0.0569 ...
##  $ concave.points_se      : num  0.0159 0.0134 0.0206 0.0187 0.0188 ...
##  $ symmetry_se            : num  0.03 0.0139 0.0225 0.0596 0.0176 ...
##  $ fractal_dimension_se   : num  0.00619 0.00353 0.00457 0.00921 0.00511 ...
##  $ radius_worst           : num  25.4 25 23.6 14.9 22.5 ...
##  $ texture_worst          : num  17.3 23.4 25.5 26.5 16.7 ...
##  $ perimeter_worst        : num  184.6 158.8 152.5 98.9 152.2 ...
##  $ area_worst             : num  2019 1956 1709 568 1575 ...
##  $ smoothness_worst       : num  0.162 0.124 0.144 0.21 0.137 ...
##  $ compactness_worst      : num  0.666 0.187 0.424 0.866 0.205 ...
##  $ concavity_worst        : num  0.712 0.242 0.45 0.687 0.4 ...
##  $ concave.points_worst   : num  0.265 0.186 0.243 0.258 0.163 ...
##  $ symmetry_worst         : num  0.46 0.275 0.361 0.664 0.236 ...
##  $ fractal_dimension_worst: num  0.1189 0.089 0.0876 0.173 0.0768 ...
```

```r
#all numeric variables
```

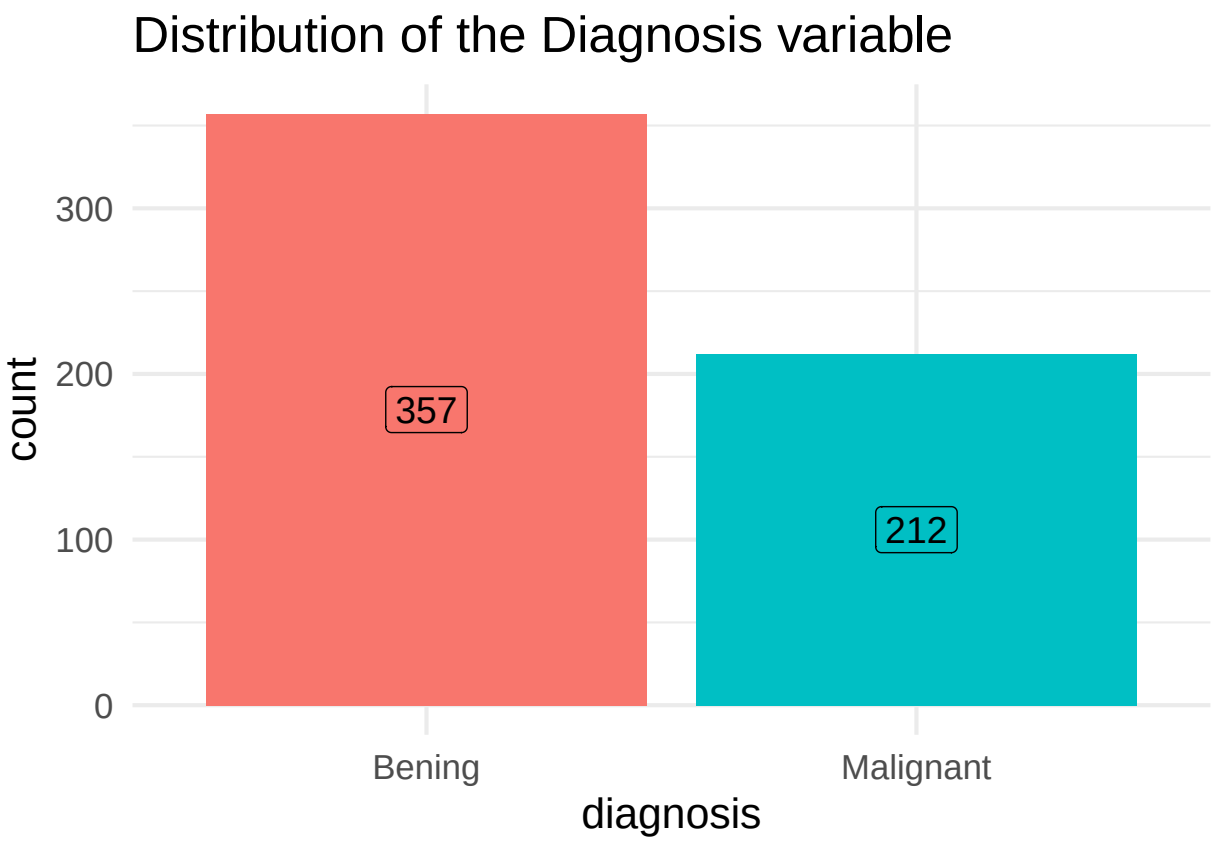
Now we know the data is clean and we can run some Visualization and Analysis

Data Visualization

Distribution of the diagnosis variable -

```r
#visualizing the diagnosis variable
p1 <- ggplot(wbcd, aes(x = diagnosis, fill = diagnosis)) +
  geom_bar(stat = "count", position = "stack", show.legend = FALSE) +
  theme_minimal(base_size = 16) +
  geom_label(stat = "count", aes(label = after_stat(count)), position = position_stack(vjust = 0.5),
             size = 5, show.legend = FALSE)

p1 +
  ggtitle("Distribution of the Diagnosis variable")
```

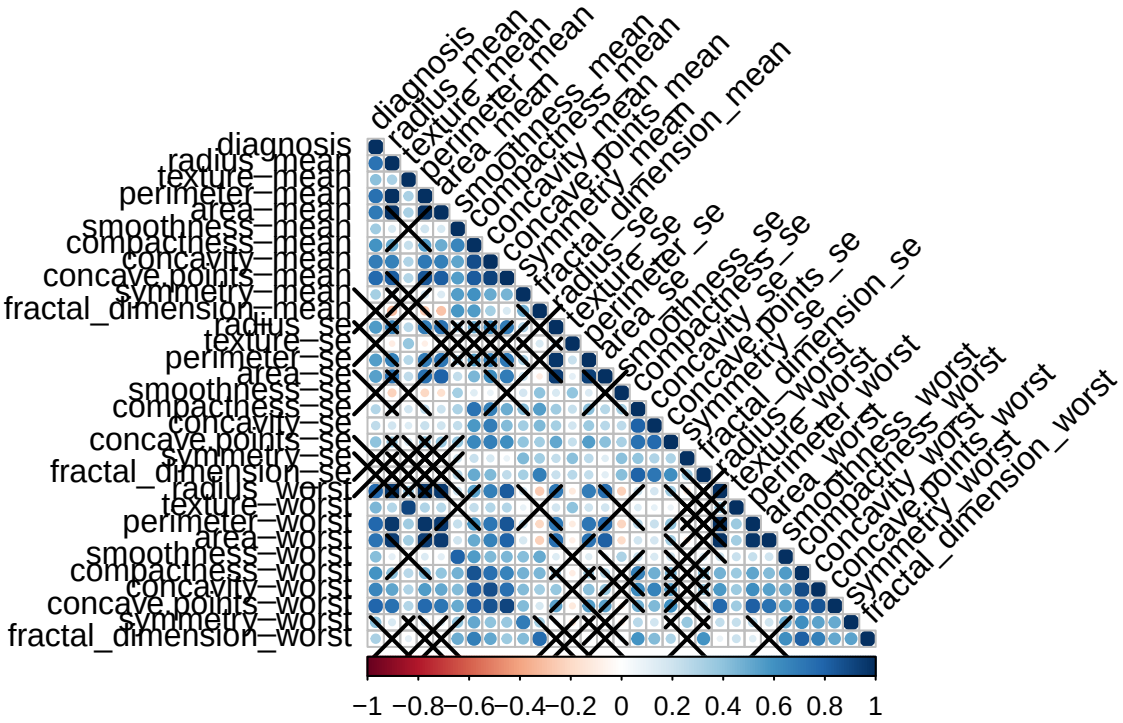


After looking at the distribution we notice that the diagnosis variable is biased.

Correlation Analysis

In this correlation matrix, correlation coefficients which has a p-value less than 0.05 are marked with a cross (which means they are significant).

```
#checking the correlation matrix
cor(wbcd_n) %>%
  corrplot(method = "circle", type = "lower", tl.col = "black", tl.srt = 45, p.mat = cor.mtest(wbcd_n)$
```



We notice that many of the independent variables are very strongly correlated, which suggests that there is multicollinearity.

Descriptive Analysis

```
#showing descriptive analysis for the numeric dataframe
describe(wbcd_n)
```

```
##                          vars   n   mean     sd median trimmed    mad    min
## diagnosis                   1 569   0.37   0.48   0.00    0.34   0.00   0.00
## radius_mean                 2 569  14.13   3.52  13.37   13.82   2.82   6.98
## texture_mean                3 569  19.29   4.30  18.84   19.04   4.17   9.71
## perimeter_mean              4 569  91.97  24.30  86.24   89.74  18.84  43.79
## area_mean                   5 569 654.89 351.91 551.10  606.13 227.28 143.50
## smoothness_mean             6 569   0.10   0.01   0.10    0.10   0.01   0.05
## compactness_mean            7 569   0.10   0.05   0.09    0.10   0.05   0.02
## concavity_mean              8 569   0.09   0.08   0.06    0.08   0.06   0.00
## concave.points_mean         9 569   0.05   0.04   0.03    0.04   0.03   0.00
## symmetry_mean              10 569   0.18   0.03   0.18    0.18   0.03   0.11
## fractal_dimension_mean     11 569   0.06   0.01   0.06    0.06   0.01   0.05
## radius_se                  12 569   0.41   0.28   0.32    0.36   0.16   0.11
## texture_se                 13 569   1.22   0.55   1.11    1.16   0.47   0.36
## perimeter_se               14 569   2.87   2.02   2.29    2.51   1.14   0.76
## area_se                    15 569  40.34  45.49  24.53   31.69  13.63   6.80
## smoothness_se              16 569   0.01   0.00   0.01    0.01   0.00   0.00
## compactness_se             17 569   0.03   0.02   0.02    0.02   0.01   0.00
## concavity_se               18 569   0.03   0.03   0.03    0.03   0.02   0.00
## concave.points_se          19 569   0.01   0.01   0.01    0.01   0.01   0.00
## symmetry_se                20 569   0.02   0.01   0.02    0.02   0.01   0.01
```

```
## fractal_dimension_se      21 569   0.00   0.00   0.00    0.00   0.00   0.00
## radius_worst              22 569  16.27   4.83  14.97   15.73   3.65   7.93
## texture_worst             23 569  25.68   6.15  25.41   25.39   6.42  12.02
## perimeter_worst           24 569 107.26  33.60  97.66  103.42  25.01  50.41
## area_worst                25 569 880.58 569.36 686.50  788.02 319.65 185.20
## smoothness_worst          26 569   0.13   0.02   0.13    0.13   0.02   0.07
## compactness_worst         27 569   0.25   0.16   0.21    0.23   0.13   0.03
## concavity_worst           28 569   0.27   0.21   0.23    0.25   0.20   0.00
## concave.points_worst      29 569   0.11   0.07   0.10    0.11   0.07   0.00
## symmetry_worst            30 569   0.29   0.06   0.28    0.28   0.05   0.16
## fractal_dimension_worst   31 569   0.08   0.02   0.08    0.08   0.01   0.06
##                             max   range skew kurtosis    se
## diagnosis                1.00    1.00 0.53    -1.73  0.02
## radius_mean             28.11   21.13 0.94     0.81  0.15
## texture_mean            39.28   29.57 0.65     0.73  0.18
## perimeter_mean         188.50  144.71 0.99     0.94  1.02
## area_mean             2501.00 2357.50 1.64     3.59 14.75
## smoothness_mean          0.16    0.11 0.45     0.82  0.00
## compactness_mean         0.35    0.33 1.18     1.61  0.00
## concavity_mean           0.43    0.43 1.39     1.95  0.00
## concave.points_mean      0.20    0.20 1.17     1.03  0.00
## symmetry_mean            0.30    0.20 0.72     1.25  0.00
## fractal_dimension_mean   0.10    0.05 1.30     2.95  0.00
## radius_se                2.87    2.76 3.07    17.45  0.01
## texture_se               4.88    4.52 1.64     5.26  0.02
## perimeter_se            21.98   21.22 3.43    21.12  0.08
## area_se                542.20  535.40 5.42    48.59  1.91
## smoothness_se            0.03    0.03 2.30    10.32  0.00
## compactness_se           0.14    0.13 1.89     5.02  0.00
## concavity_se             0.40    0.40 5.08    48.24  0.00
## concave.points_se        0.05    0.05 1.44     5.04  0.00
## symmetry_se              0.08    0.07 2.18     7.78  0.00
## fractal_dimension_se     0.03    0.03 3.90    25.94  0.00
## radius_worst            36.04   28.11 1.10     0.91  0.20
## texture_worst           49.54   37.52 0.50     0.20  0.26
## perimeter_worst        251.20  200.79 1.12     1.04  1.41
## area_worst            4254.00 4068.80 1.85     4.32 23.87
## smoothness_worst         0.22    0.15 0.41     0.49  0.00
## compactness_worst        1.06    1.03 1.47     2.98  0.01
## concavity_worst          1.25    1.25 1.14     1.57  0.01
## concave.points_worst     0.29    0.29 0.49    -0.55  0.00
## symmetry_worst           0.66    0.51 1.43     4.37  0.00
## fractal_dimension_worst  0.21    0.15 1.65     5.16  0.00
```

We see that radius_se (3.07), perimeter_se (3.43), area_se(5.42), concavity_se (5.08) and fractal_dimension_se (3.90) are some of the highly skewed variables.
We see observe that texture_worse(0.50) and diagnosis(0.53) are approximately symmetric.
The highest mean values were found for area_mean (654.89), area_worst (880.58) and perimeter_worst (107.26).
The lowest mean values was for fractal_dimension_se (0.00).

Statstical Analysis

Before running Factor Analysis, we need to check for the factoribility of the dataset by running the below tests

```
#Testing KMO Sampling Adequacy
KMO(wbcd_n)
```

```
## Kaiser-Meyer-Olkin factor adequacy
## Call: KMO(r = wbcd_n)
## Overall MSA =  0.84
## MSA for each item =
##               diagnosis             radius_mean            texture_mean
##                    0.99                    0.84                    0.66
##          perimeter_mean               area_mean         smoothness_mean
##                    0.86                    0.87                    0.82
##        compactness_mean          concavity_mean     concave.points_mean
##                    0.88                    0.90                    0.91
##           symmetry_mean  fractal_dimension_mean               radius_se
##                    0.83                    0.83                    0.84
##              texture_se            perimeter_se                 area_se
##                    0.49                    0.85                    0.86
##           smoothness_se          compactness_se            concavity_se
##                    0.65                    0.87                    0.83
##       concave.points_se             symmetry_se    fractal_dimension_se
##                    0.84                    0.58                    0.81
##            radius_worst           texture_worst         perimeter_worst
##                    0.83                    0.62                    0.89
##              area_worst        smoothness_worst       compactness_worst
##                    0.83                    0.76                    0.86
##         concavity_worst    concave.points_worst          symmetry_worst
##                    0.91                    0.90                    0.70
## fractal_dimension_worst
##                    0.82
```

```
#Overall MSA = 0.84
```

```
#Testing Bartlett's Test of Sphericity
bart_spher(wbcd_n)
```

```
##  Bartlett's Test of Sphericity
##
## Call: bart_spher(x = wbcd_n)
##
##      X2 = 40167.506
##      df = 465
## p-value < 2.22e-16
```

```
#p-value < 2.22e-16
```

```r
#Checking the Cronbach's Alpha
cronbach.alpha(wbcd_n)
```

```
##
## Cronbach's alpha for the 'wbcd_n' data-set
##
## Items: 31
## Sample units: 569
## alpha: 0.585
```

```r
#raw_alpha = 0.58
```

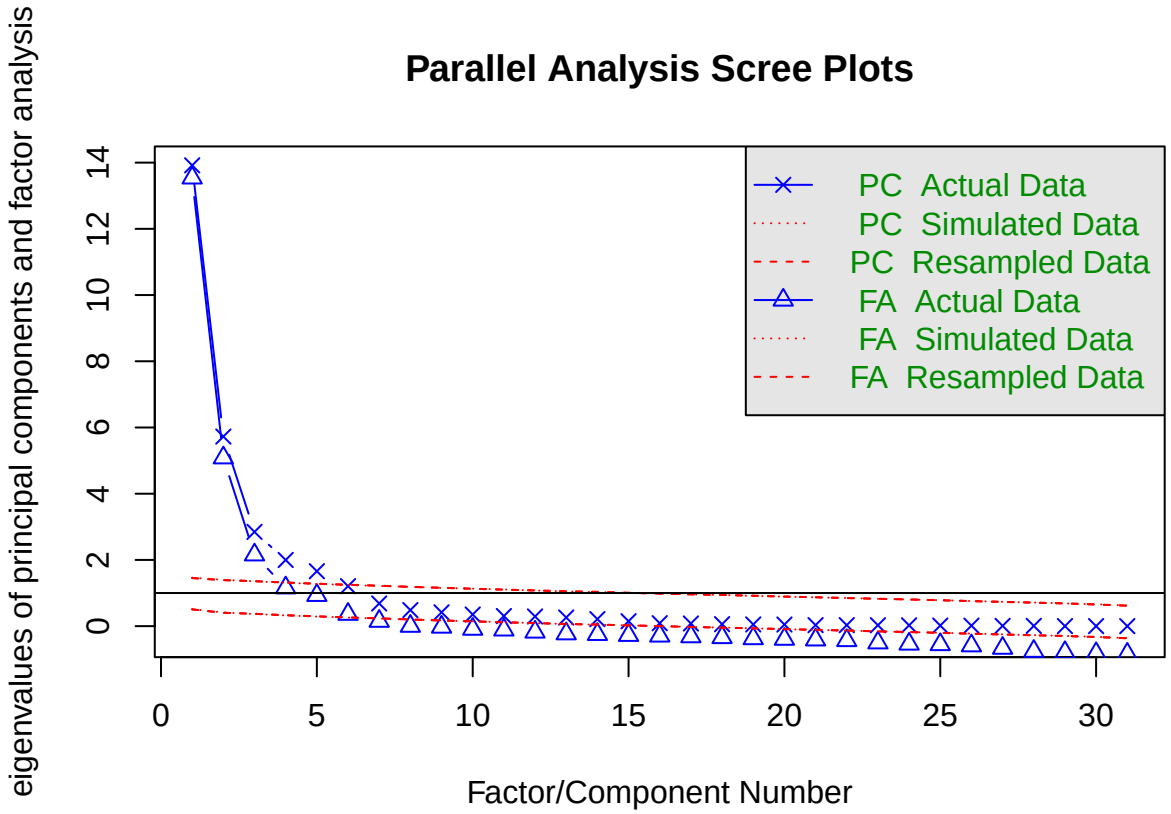
The KMO Sampling Test gave us a MSA value of 0.84, which confirms that the sample used is sufficient.
We see the the Bartlett's Test of Sphericity has a p-value of less than 0.05 demonstrating that the correlation matrix is not an identity matrix, therefore providing justification to use Factor Analysis.
Usual we accept a sample only when the Cronbach's alpha is greater than 0.6 but I am making an exception with my dataset.

Parallel Analysis

Parallel Analysis can helps us determine how many factors we need to use in factor analysis.
Parallel Analysis can be used as a guess and not a final answer, it gives us something to get started.

```r
#running parallel analysis
comp <- fa.parallel(wbcd_n)
```

```
## Warning in fa.stats(r = r, f = f, phi = phi, n.obs = n.obs, np.obs = np.obs, :
## The estimated weights for the factor scores are probably incorrect.  Try a
## different factor score estimation method.
```




```
## Parallel analysis suggests that the number of factors =  6  and the number of components =  5
```

```
comp
```

```
## Call: fa.parallel(x = wbcd_n)
## Parallel analysis suggests that the number of factors =  6  and the number of components =  5
##
##  Eigen Values of
##   Original factors Resampled data Simulated data Original components
## 1            13.54           0.51           0.51                13.92
## 2             5.08           0.40           0.41                 5.73
## 3             2.15           0.37           0.37                 2.85
## 4             1.16           0.33           0.32                 2.00
## 5             0.93           0.30           0.29                 1.66
## 6             0.36           0.26           0.26                 1.21
##   Resampled components Simulated components
## 1                 1.45                  1.46
## 2                 1.39                  1.40
## 3                 1.36                  1.35
## 4                 1.32                  1.31
## 5                 1.28                  1.27
## 6                 1.25                  1.24
```

Parallel Analysis suggests that we should be using 6 factors but let's take a look at eigenvalues which are greater than 1

```r
#checking for eigenvalues which are greater than 1
sum(comp$fa.values>1)
```

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

Now since we know that there are four factors which have eigenvalues that are greater than 1, we will start by using 4 factors

Common Factor Analysis

```r
#Conducting factor analysis
fit = factanal(wbcd_n[,-1], 4, rotation = "varimax", lower = 0.1)
print(fit$loadings, cutoff=0.5, sort=T)
```

```
##
## Loadings:
##                         Factor1 Factor2 Factor3 Factor4
## radius_mean              0.943
## perimeter_mean           0.941
## area_mean                0.962
## concave.points_mean      0.782   0.548
## radius_se                0.828
## perimeter_se             0.814           0.503
## area_se                  0.874
## radius_worst             0.939
## perimeter_worst          0.932
## area_worst               0.945
## smoothness_mean                  0.596
## compactness_mean                 0.828
## concavity_mean           0.631   0.690
## symmetry_mean                    0.545
## fractal_dimension_mean           0.705
## compactness_se                   0.686
## concavity_se                     0.582
## fractal_dimension_se             0.546   0.545
## smoothness_worst                 0.641
## compactness_worst                0.870
## concavity_worst                  0.812
## concave.points_worst     0.660   0.671
## symmetry_worst                   0.596
## fractal_dimension_worst          0.870
## texture_se                               0.528
## smoothness_se                            0.598
## symmetry_se                              0.569
## texture_mean                                     0.914
## texture_worst                                    0.918
## concave.points_se
##
##                Factor1 Factor2 Factor3 Factor4
## SS loadings      9.854   7.634   3.018   2.077
## Proportion Var   0.328   0.254   0.101   0.069
## Cumulative Var   0.328   0.583   0.684   0.753
```

```r
#Displaying the summary
summary(fit)
```

```
##              Length Class    Mode
## converged      1    -none-   logical
## loadings     120    loadings numeric
## uniquenesses  30    -none-   numeric
## correlation  900    -none-   numeric
## criteria       3    -none-   numeric
## factors        1    -none-   numeric
## dof            1    -none-   numeric
## method         1    -none-   character
## rotmat        16    -none-   numeric
## STATISTIC      1    -none-   numeric
## PVAL           1    -none-   numeric
## n.obs          1    -none-   numeric
## call           5    -none-   call
```

Interpretation -

The variables with high factor loadings in Factor 1 are radius, parameter and area which are related to the size of the nucleus. The larger these variables are, the larger these values become.
The variables with high factor loadings in Factor 2 are those related to the distortion of the contour of the cell nucleus, such as fractal_dimension, smoothness, compactness and concavity.
The variable with highest factor loading in Factor 3 is smoothness_se which drives the Factor 3.
The variables with high factor loadings in Factor 4 are mainly related to texture and larger these values are, the larger these values become.
We also observe some cross-loadings between Factor 1 and Factor 2 and Factor 3 and Factor 4.
The four factors explain 75% of the variance.

Names of the components -

Factor 1 - size, as it speaks about how large a nuclei is
Factor 2 - distortion, as it describes the distorted cells outline
Factor 3 - variety, as it tells us the variety of cell nuclei
Factor 4 - texture, as it talks about the texture of the nuclei

Conclusion

We arrive at a conclusion that there are four main characteristics which are needed to detect breast cancer and among these four characteristics, size is one of the most important characteristics to consider.
In actual medical practice, the degree of "nuclear atypia" of cells is used to classify the malignancy of breast cancer. The larger the cell nucleus, the more chromatin is increased and unevenly distributed, and the more distorted the nuclear outline, the more abnormal the cell is considered to be. [3]
The above mentioned study confirms are findings.

References

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2.American Cancer Society (n.d.). Fine Needle Aspiration (FNA) of the Breast. Cancer.org. https://www.cancer.org/cancer/types/breast-cancer/screening-tests-and-early-detection/breast-biopsy/fine-needle-aspiration-biopsy-of-the-breast.html#:~:text=During%20a%20fine%20needle%20aspiration,needle%20biopsy%20is%20often%

3.Okudela K. (2014). An association between nuclear morphology and immunohistochemical expression of p53 and p16INK4A in lung cancer cells. Medical molecular morphology, 47(3), 130–136. https://doi.org/10.1007/s00795-013-0052-x