breast_cancer_model_analysis.R

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1. Introduction

Disease prediction has long been regarded as a critical topic. With big data and Machine Learning growth in biomedical and healthcare communities, accurate analysis of medical data benefits early disease detection, patient care, and community services.

2. Objective

Build Machine Learning Models to predict the type of Breast Cancer (Malignant or Benign) as well as identify the drivers of cancer.

3. Approach

- • Exploring features and Data Preparation which includes missing value treatment and Outlier Detection
- • Visualizing relationships among features
- • Split the data into train and test data and build sophisticated Machine Learning models
- • Evaluating Model performance on test data using Precision, Recall, Accuracy and ROC curve metrics
- • Determining the factors driving the cancer.
- • Choosing best model based on the accuracy and other measures.

5. Problem Statement

1. Build Machine Learning Models to predict the type of Breast Cancer (Malignant or Benign) as well as identify the drivers of cancer.

Apply the concepts of - Logistic Regression and Random Forest.

```
setwd("C:/Users/tsraj/Desktop/Acadgild students projects/project4")
library(readr)
CancerData <- read_csv("CancerData.csv")

## Warning: Missing column names filled in: 'X33' [33]

## Parsed with column specification:
## cols(
##   .default = col_double(),
##   id = col_integer(),
##   diagnosis = col_character(),
##   X33 = col_character()
## )

## See spec(...) for full column specifications.
## Warning in rbind(names(probs), probs_f): number of columns of result is
not
## a multiple of vector length (arg 1)
```

```
## Warning: 569 parsing failures.
## row # A tibble: 5 x 5 col     row col   expected   actual     file
expected   <int> <chr> <chr>      <chr>      <chr>            actual 1     1
<NA>  33 columns 32 columns 'CancerData.csv' file 2     2 <NA>  33 columns 32
columns 'CancerData.csv' row 3     3 <NA>  33 columns 32 columns
'CancerData.csv' col 4     4 <NA>  33 columns 32 columns 'CancerData.csv'
expected 5     5 <NA>  33 columns 32 columns 'CancerData.csv'
## ... ................. ...
.................................................... ........
.................................................... ......
.................................................... ....
.................................................... ...
.................................................... ...
.................................................... ........
....................................................
## See problems(...) for more details.
```

```
View(CancerData)
summary(CancerData)
```

```
##        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
##  Min.   :0.00000   Min.   :0.00000     Min.   :0.1060
##  1st Qu.:0.02956   1st Qu.:0.02031     1st Qu.:0.1619
##  Median :0.06154   Median :0.03350     Median :0.1792
##  Mean   :0.08880   Mean   :0.04892     Mean   :0.1812
##  3rd Qu.:0.13070   3rd Qu.:0.07400     3rd Qu.:0.1957
##  Max.   :0.42680   Max.   :0.20120     Max.   :0.3040
##  fractal_dimension_mean   radius_se        texture_se      perimeter_se
##  Min.   :0.04996        Min.   :0.1115   Min.   :0.3602   Min.   : 0.757
##  1st Qu.:0.05770        1st Qu.:0.2324   1st Qu.:0.8339   1st Qu.: 1.606
##  Median :0.06154        Median :0.3242   Median :1.1080   Median : 2.287
##  Mean   :0.06280        Mean   :0.4052   Mean   :1.2169   Mean   : 2.866
##  3rd Qu.:0.06612        3rd Qu.:0.4789   3rd Qu.:1.4740   3rd Qu.: 3.357
##  Max.   :0.09744        Max.   :2.8730   Max.   :4.8850   Max.   :21.980
##     area_se       smoothness_se      compactness_se      concavity_se
##  Min.   :  6.802   Min.   :0.001713   Min.   :0.002252   Min.   :0.00000
##  1st Qu.: 17.850   1st Qu.:0.005169   1st Qu.:0.013080   1st Qu.:0.01509
##  Median : 24.530   Median :0.006380   Median :0.020450   Median :0.02589
##  Mean   : 40.337   Mean   :0.007041   Mean   :0.025478   Mean   :0.03189
##  3rd Qu.: 45.190   3rd Qu.:0.008146   3rd Qu.:0.032450   3rd Qu.:0.04205
##  Max.   :542.200   Max.   :0.031130   Max.   :0.135400   Max.   :0.39600
##  concave points_se   symmetry_se       fractal_dimension_se
##  Min.   :0.000000   Min.   :0.007882   Min.   :0.0008948
##  1st Qu.:0.007638   1st Qu.:0.015160   1st Qu.:0.0022480
##  Median :0.010930   Median :0.018730   Median :0.0031870
##  Mean   :0.011796   Mean   :0.020542   Mean   :0.0037949
##  3rd Qu.:0.014710   3rd Qu.:0.023480   3rd Qu.:0.0045580
##  Max.   :0.052790   Max.   :0.078950   Max.   :0.0298400
##   radius_worst   texture_worst   perimeter_worst    area_worst
##  Min.   : 7.93   Min.   :12.02   Min.   : 50.41   Min.   : 185.2
##  1st Qu.:13.01   1st Qu.:21.08   1st Qu.: 84.11   1st Qu.: 515.3
##  Median :14.97   Median :25.41   Median : 97.66   Median : 686.5
##  Mean   :16.27   Mean   :25.68   Mean   :107.26   Mean   : 880.6
##  3rd Qu.:18.79   3rd Qu.:29.72   3rd Qu.:125.40   3rd Qu.:1084.0
##  Max.   :36.04   Max.   :49.54   Max.   :251.20   Max.   :4254.0
##  smoothness_worst  compactness_worst concavity_worst  concave points_worst
##  Min.   :0.07117   Min.   :0.02729   Min.   :0.0000   Min.   :0.00000
##  1st Qu.:0.11660   1st Qu.:0.14720   1st Qu.:0.1145   1st Qu.:0.06493
##  Median :0.13130   Median :0.21190   Median :0.2267   Median :0.09993
##  Mean   :0.13237   Mean   :0.25427   Mean   :0.2722   Mean   :0.11461
##  3rd Qu.:0.14600   3rd Qu.:0.33910   3rd Qu.:0.3829   3rd Qu.:0.16140
##  Max.   :0.22260   Max.   :1.05800   Max.   :1.2520   Max.   :0.29100
##  symmetry_worst   fractal_dimension_worst     X33
##  Min.   :0.1565   Min.   :0.05504         Length:569
##  1st Qu.:0.2504   1st Qu.:0.07146         Class :character
##  Median :0.2822   Median :0.08004         Mode  :character
##  Mean   :0.2901   Mean   :0.08395
##  3rd Qu.:0.3179   3rd Qu.:0.09208
##  Max.   :0.6638   Max.   :0.20750
```

```
dim(CancerData)
```

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

```
names(CancerData)
```

```
##  [1] "id"                      "diagnosis"
##  [3] "radius_mean"             "texture_mean"
##  [5] "perimeter_mean"          "area_mean"
##  [7] "smoothness_mean"         "compactness_mean"
##  [9] "concavity_mean"          "concave points_mean"
## [11] "symmetry_mean"           "fractal_dimension_mean"
## [13] "radius_se"               "texture_se"
## [15] "perimeter_se"            "area_se"
## [17] "smoothness_se"           "compactness_se"
## [19] "concavity_se"            "concave points_se"
## [21] "symmetry_se"             "fractal_dimension_se"
## [23] "radius_worst"            "texture_worst"
## [25] "perimeter_worst"         "area_worst"
## [27] "smoothness_worst"        "compactness_worst"
## [29] "concavity_worst"         "concave points_worst"
## [31] "symmetry_worst"          "fractal_dimension_worst"
## [33] "X33"
```

```
library(mice)
```

```
## Loading required package: lattice
```

```
## 
## Attaching package: 'mice'
```

```
## The following objects are masked from 'package:base':
## 
##     cbind, rbind
```

```
library(readr,dplyr)
library("ggplot2")
library("corrplot")
```

```
## corrplot 0.84 loaded
```

```
library("gridExtra")
library("pROC")
```

```
## Type 'citation("pROC")' for a citation.
```

```
## 
## Attaching package: 'pROC'
```

```
## The following objects are masked from 'package:stats':
## 
##     cov, smooth, var
```

```
library("MASS")
library("caTools")
library("caret")
library(randomForest)
```

```
## randomForest 4.6-14
```

```
## Type rfNews() to see new features/changes/bug fixes.
```

```
## 
## Attaching package: 'randomForest'
## The following object is masked from 'package:gridExtra':
##
##     combine
```

```
## The following object is masked from 'package:ggplot2':
##
##     margin
```

```
library(rpart)
library(rpart.plot)
library(rattle)
```

```
## Rattle: A free graphical interface for data science with R.
## Version 5.2.0 Copyright (c) 2006-2018 Togaware Pty Ltd.
## Type 'rattle()' to shake, rattle, and roll your data.
```

```
##
## Attaching package: 'rattle'
```

```
## The following object is masked from 'package:randomForest':
##
##     importance
```

```
data<-CancerData
library(Amelia)
```

```
## Loading required package: Rcpp
```

```
## ##
## ## Amelia II: Multiple Imputation
## ## (Version 1.7.5, built: 2018-05-07)
## ## Copyright (C) 2005-2018 James Honaker, Gary King and Matthew Blackwell
## ## Refer to http://gking.harvard.edu/amelia/ for more information
## ##
```

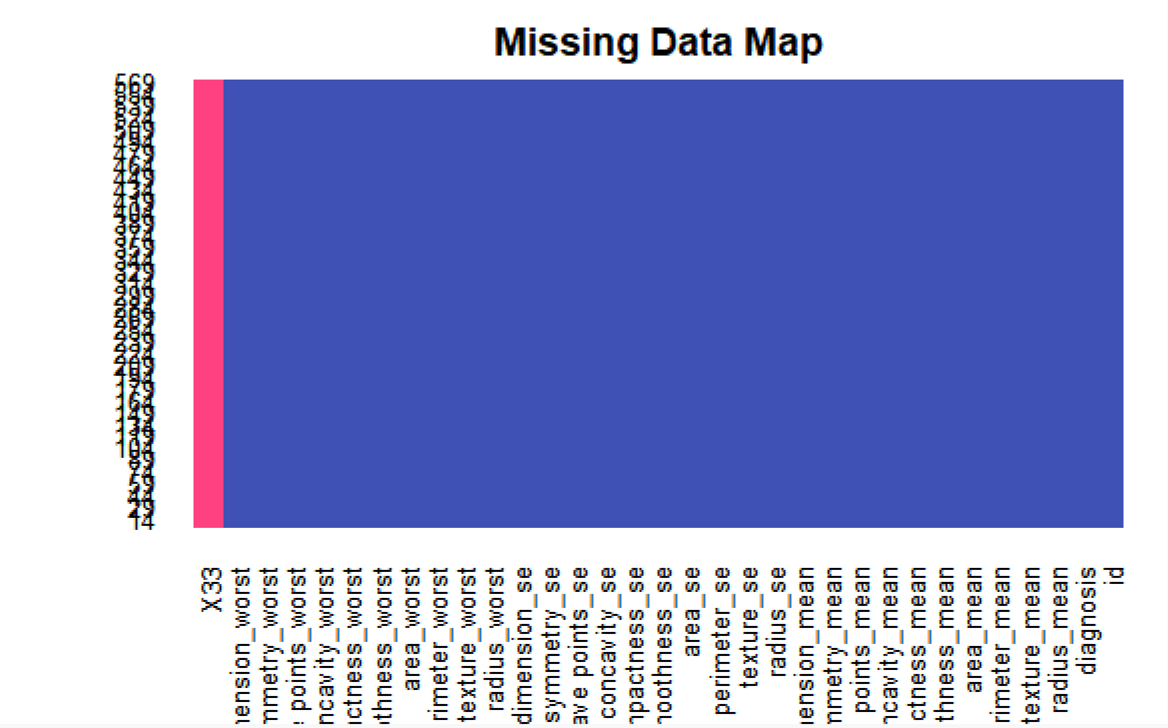
```
str(data)
```

```
## Classes 'tbl_df', 'tbl' and 'data.frame':    569 obs. of  33 variables:
##  $ id                     : int  842302 842517 84300903 84348301 84358402
843786 844359 84458202 844981 84501001 ...
##  $ 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 ...
##  $ X33                    : chr  NA NA NA NA ...
##  - attr(*, "problems")=Classes 'tbl_df', 'tbl' and 'data.frame': 569 obs.
of  5 variables:
##   ..$ row     : int  1 2 3 4 5 6 7 8 9 10 ...
##   ..$ col     : chr  NA NA NA NA ...
##   ..$ expected: chr  "33 columns" "33 columns" "33 columns" "33 columns"
...
##   ..$ actual  : chr  "32 columns" "32 columns" "32 columns" "32 columns"
...
##   ..$ file    : chr  "'CancerData.csv'" "'CancerData.csv'"
"'CancerData.csv'" "'CancerData.csv'" ...
##  - attr(*, "spec")=List of 2
##   ..$ cols   :List of 33
##   .. ..$ id                     : list()
##   .. .. ..- attr(*, "class")= chr  "collector_integer" "collector"
##   .. ..$ diagnosis              : list()
##   .. .. ..- attr(*, "class")= chr  "collector_character" "collector"
##   .. ..$ radius_mean            : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ texture_mean           : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ perimeter_mean         : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ area_mean              : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ smoothness_mean        : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ compactness_mean       : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concavity_mean         : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concave points_mean    : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ symmetry_mean          : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ fractal_dimension_mean : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ radius_se              : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ texture_se             : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ perimeter_se           : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ area_se                : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ smoothness_se          : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ compactness_se         : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concavity_se           : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concave points_se      : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ symmetry_se            : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ fractal_dimension_se   : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ radius_worst           : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ texture_worst          : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ perimeter_worst        : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ area_worst             : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ smoothness_worst       : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ compactness_worst      : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concavity_worst        : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ concave points_worst   : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ symmetry_worst         : list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ fractal_dimension_worst: list()
##   .. .. ..- attr(*, "class")= chr  "collector_double" "collector"
##   .. ..$ X33                    : list()
##   .. .. ..- attr(*, "class")= chr  "collector_character" "collector"
##   ..$ default: list()
##   .. ..- attr(*, "class")= chr  "collector_guess" "collector"
##   ..- attr(*, "class")= chr "col_spec"
```

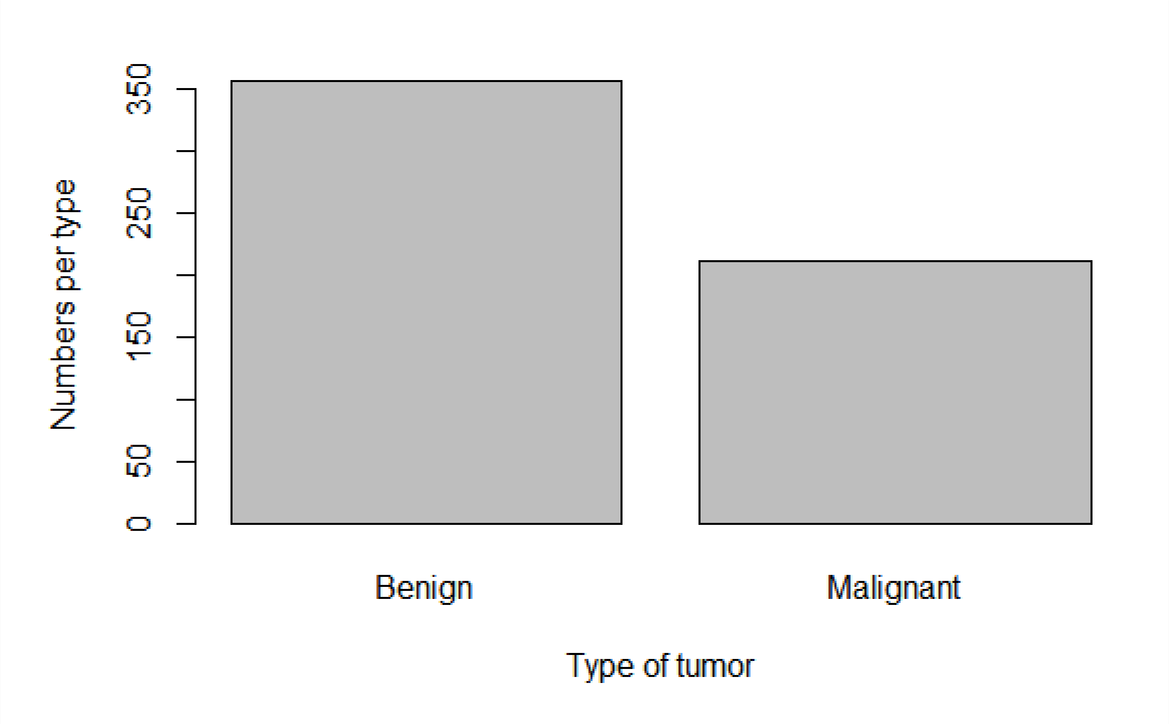
```
any(is.na(data))
```

```
## [1] TRUE
```

```
missmap(CancerData, main="Missing Data Map", col=c("#FF4081", "#3F51B5"),
    legend=FALSE)
```

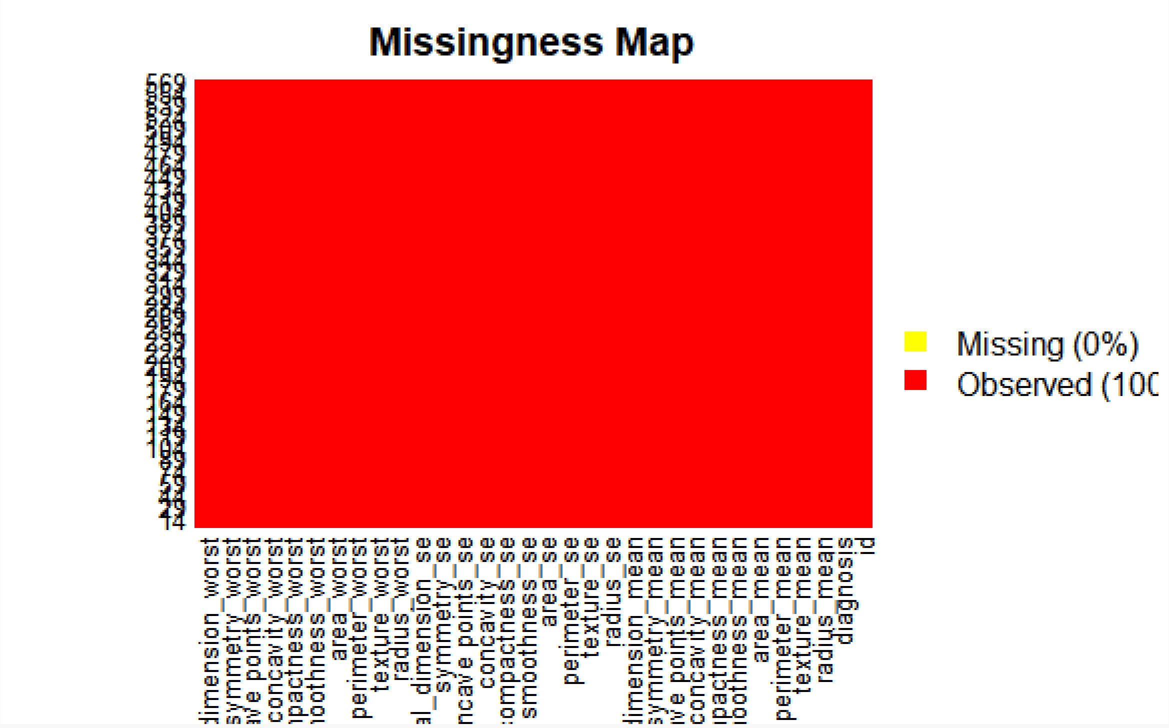


```
data<-CancerData
data[,33]<-NULL


barplot(table(data$diagnosis), xlab = "Type of tumor", ylab="Numbers per type")
```



```
# visualize the missing values using the missing map from the Amelia package
missmap(data,col=c("yellow","red"))
```

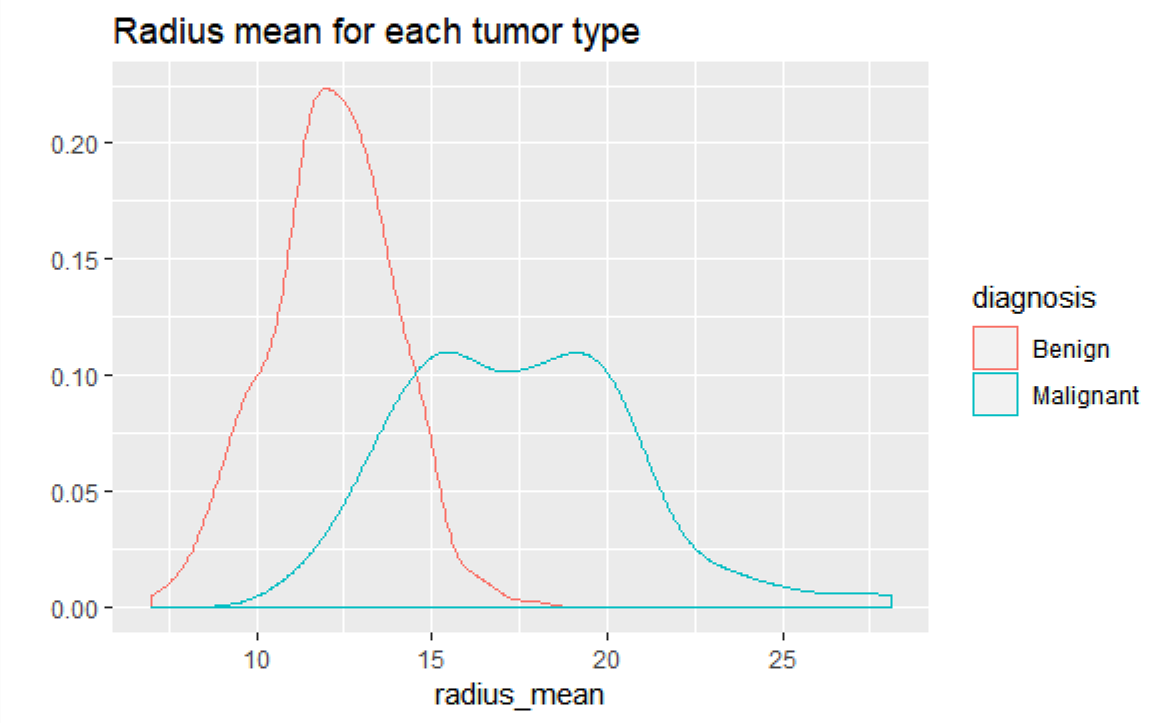
```
## Warning in if (class(obj) == "amelia") {: the condition has length > 1 and
## only the first element will be used
```



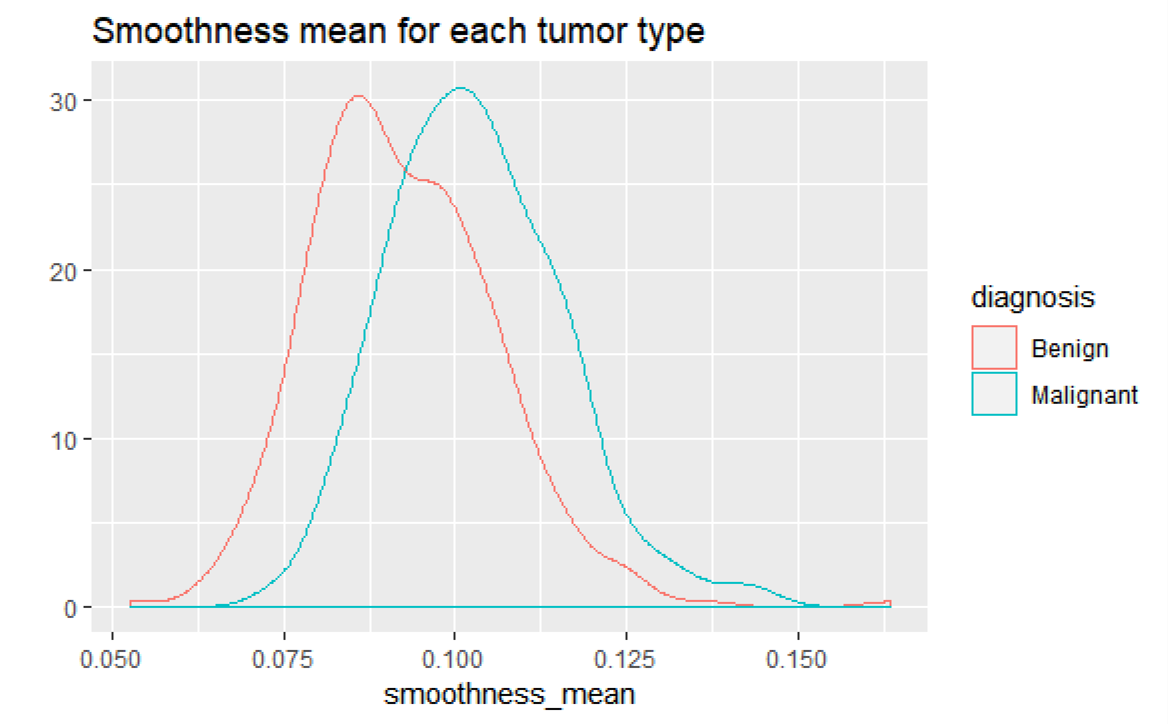
```
data$diagnosis<-as.factor(data$diagnosis)
data[,33]<-NULL
summary(data)
```

```
##        id            diagnosis  radius_mean      texture_mean
##  Min.   :     8670   B:357     Min.   : 6.981   Min.   : 9.71
##  1st Qu.:   869218   M:212     1st Qu.:11.700   1st Qu.:16.17
##  Median :   906024             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
##  Min.   :0.00000   Min.   :0.00000     Min.   :0.1060
##  1st Qu.:0.02956   1st Qu.:0.02031     1st Qu.:0.1619
##  Median :0.06154   Median :0.03350     Median :0.1792
##  Mean   :0.08880   Mean   :0.04892     Mean   :0.1812
##  3rd Qu.:0.13070   3rd Qu.:0.07400     3rd Qu.:0.1957
##  Max.   :0.42680   Max.   :0.20120     Max.   :0.3040
##  fractal_dimension_mean   radius_se        texture_se      perimeter_se
##  Min.   :0.04996         Min.   :0.1115   Min.   :0.3602   Min.   : 0.757
##  1st Qu.:0.05770         1st Qu.:0.2324   1st Qu.:0.8339   1st Qu.: 1.606
##  Median :0.06154         Median :0.3242   Median :1.1080   Median : 2.287
##  Mean   :0.06280         Mean   :0.4052   Mean   :1.2169   Mean   : 2.866
##  3rd Qu.:0.06612         3rd Qu.:0.4789   3rd Qu.:1.4740   3rd Qu.: 3.357
##  Max.   :0.09744         Max.   :2.8730   Max.   :4.8850   Max.   :21.980
##     area_se        smoothness_se      compactness_se      concavity_se
##  Min.   :  6.802   Min.   :0.001713   Min.   :0.002252   Min.   :0.00000
##  1st Qu.: 17.850   1st Qu.:0.005169   1st Qu.:0.013080   1st Qu.:0.01509
##  Median : 24.530   Median :0.006380   Median :0.020450   Median :0.02589
##  Mean   : 40.337   Mean   :0.007041   Mean   :0.025478   Mean   :0.03189
##  3rd Qu.: 45.190   3rd Qu.:0.008146   3rd Qu.:0.032450   3rd Qu.:0.04205
##  Max.   :542.200   Max.   :0.031130   Max.   :0.135400   Max.   :0.39600
##  concave points_se   symmetry_se       fractal_dimension_se
##  Min.   :0.000000   Min.   :0.007882   Min.   :0.0008948
##  1st Qu.:0.007638   1st Qu.:0.015160   1st Qu.:0.0022480
##  Median :0.010930   Median :0.018730   Median :0.0031870
##  Mean   :0.011796   Mean   :0.020542   Mean   :0.0037949
##  3rd Qu.:0.014710   3rd Qu.:0.023480   3rd Qu.:0.0045580
##  Max.   :0.052790   Max.   :0.078950   Max.   :0.0298400
##   radius_worst   texture_worst   perimeter_worst    area_worst
##  Min.   : 7.93   Min.   :12.02   Min.   : 50.41   Min.   : 185.2
##  1st Qu.:13.01   1st Qu.:21.08   1st Qu.: 84.11   1st Qu.: 515.3
##  Median :14.97   Median :25.41   Median : 97.66   Median : 686.5
##  Mean   :16.27   Mean   :25.68   Mean   :107.26   Mean   : 880.6
##  3rd Qu.:18.79   3rd Qu.:29.72   3rd Qu.:125.40   3rd Qu.:1084.0
##  Max.   :36.04   Max.   :49.54   Max.   :251.20   Max.   :4254.0
##  smoothness_worst  compactness_worst concavity_worst  concave points_worst
##  Min.   :0.07117   Min.   :0.02729   Min.   :0.0000   Min.   :0.00000
##  1st Qu.:0.11660   1st Qu.:0.14720   1st Qu.:0.1145   1st Qu.:0.06493
##  Median :0.13130   Median :0.21190   Median :0.2267   Median :0.09993
##  Mean   :0.13237   Mean   :0.25427   Mean   :0.2722   Mean   :0.11461
##  3rd Qu.:0.14600   3rd Qu.:0.33910   3rd Qu.:0.3829   3rd Qu.:0.16140
##  Max.   :0.22260   Max.   :1.05800   Max.   :1.2520   Max.   :0.29100
##  symmetry_worst   fractal_dimension_worst
##  Min.   :0.1565   Min.   :0.05504
##  1st Qu.:0.2504   1st Qu.:0.07146
##  Median :0.2822   Median :0.08004
##  Mean   :0.2901   Mean   :0.08395
##  3rd Qu.:0.3179   3rd Qu.:0.09208
##  Max.   :0.6638   Max.   :0.20750
```

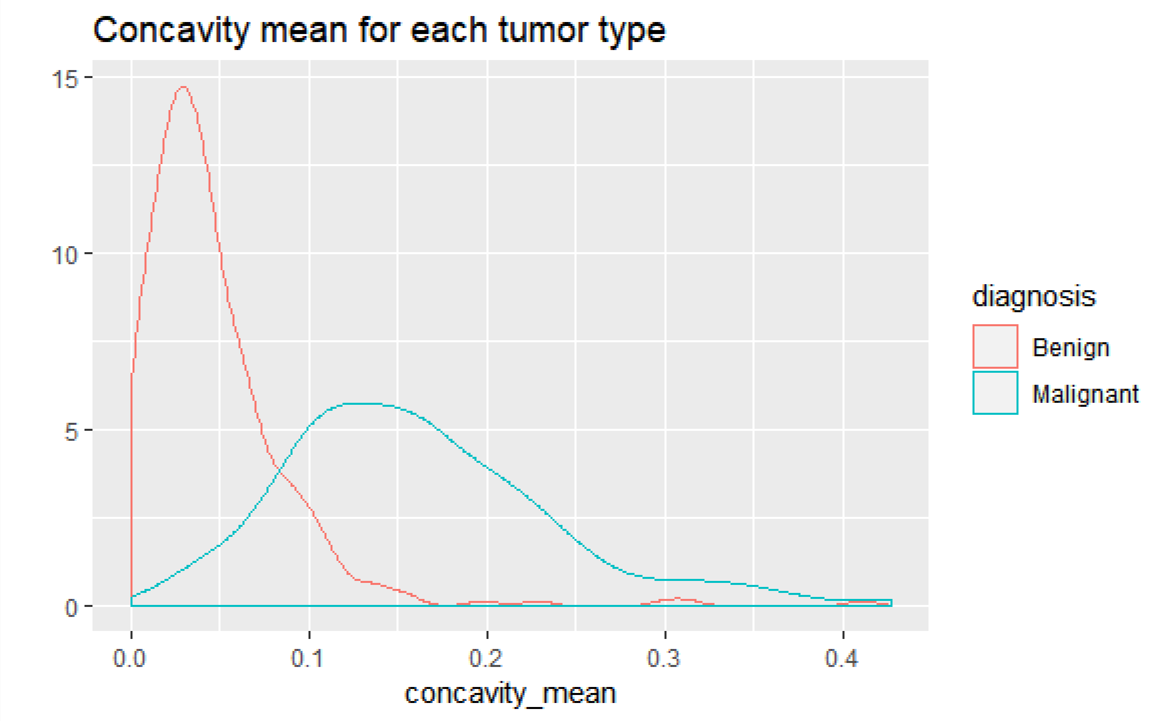
```
qplot(radius_mean, data=data, colour=diagnosis, geom="density",
   main="Radius mean for each tumor type")
```



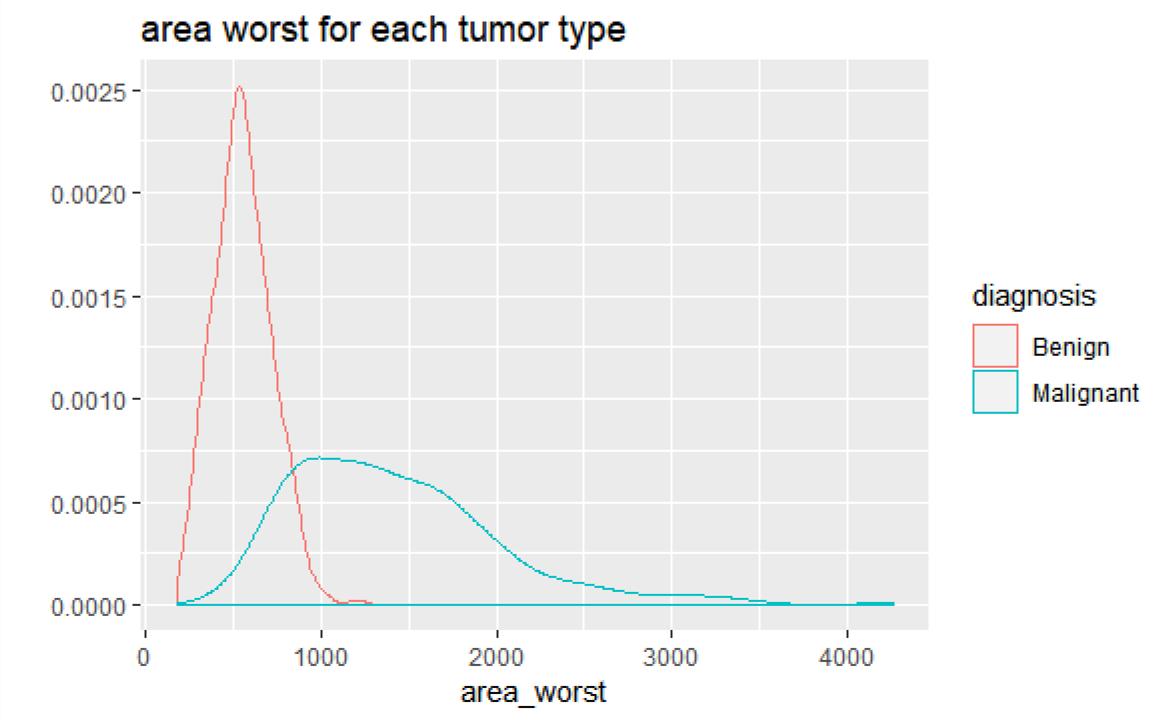
```
qplot(smoothness_mean, data=data, colour=diagnosis, geom="density",
    main="Smoothness mean for each tumor type")
```



```
qplot(concavity_mean, data=data, colour=diagnosis, geom="density",
    main="Concavity mean for each tumor type")
```

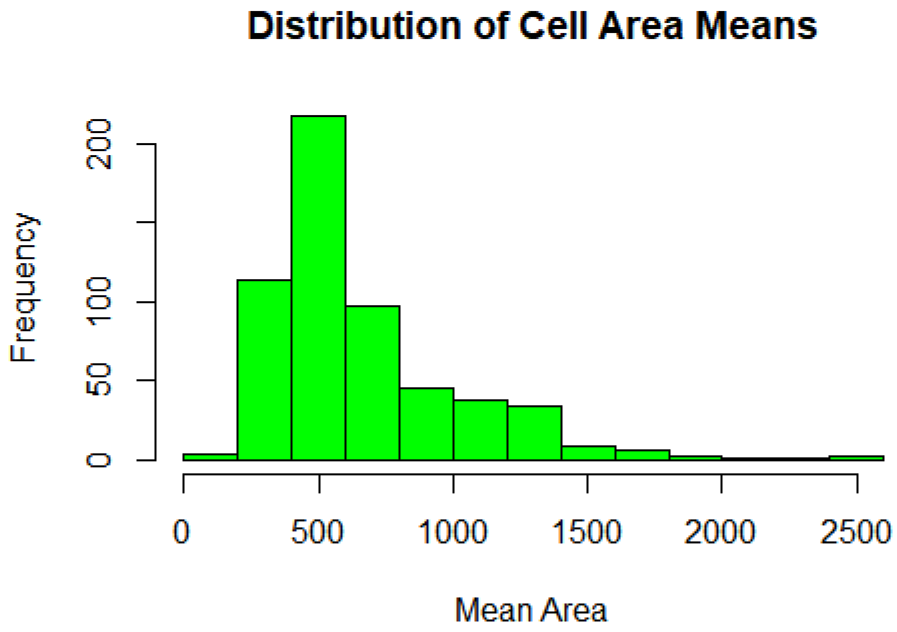


```
qplot(area_worst , data=data, colour=diagnosis, geom="density",
    main="area worst for each tumor type")
```

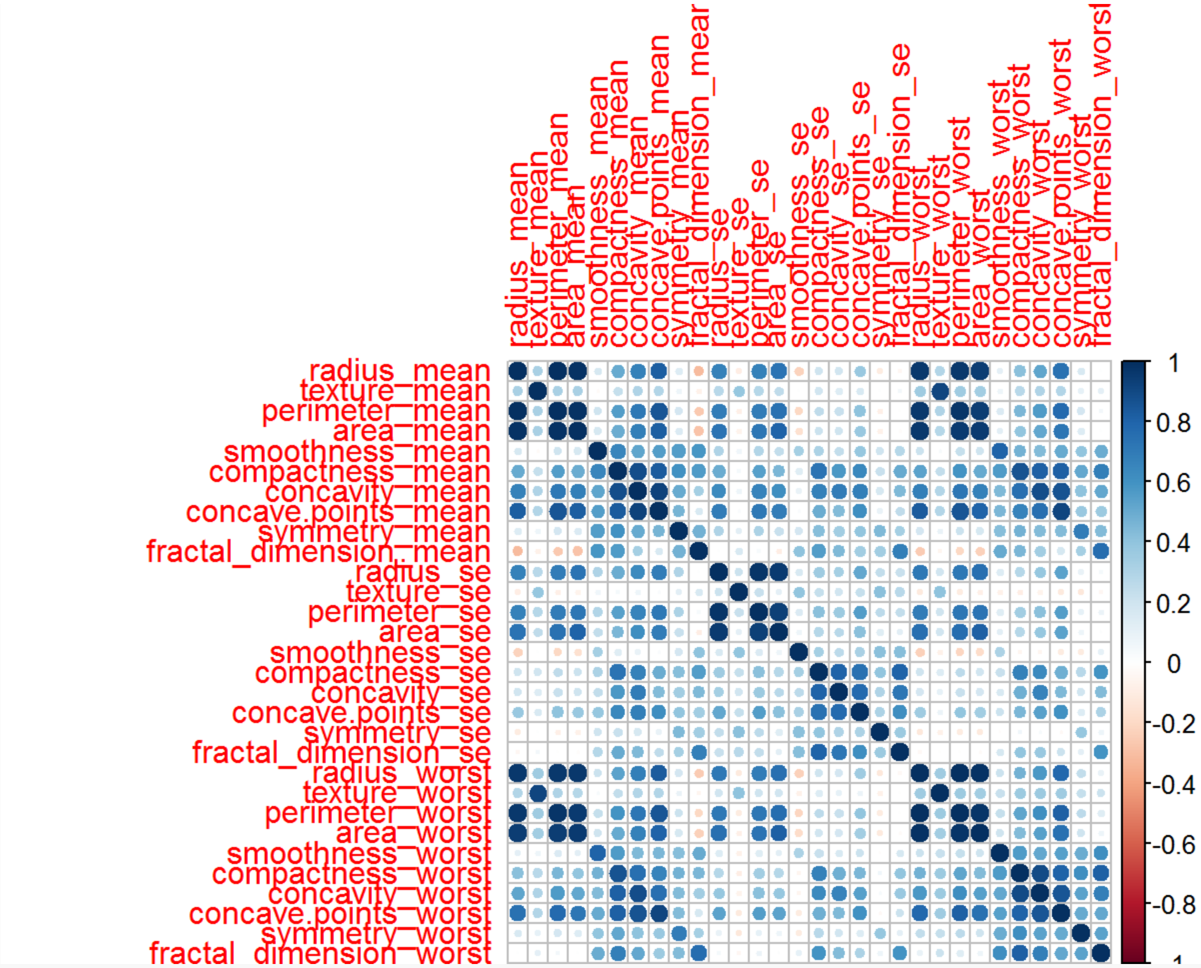


```
# Looking at distribution for area.mean variable
plot.new()
```

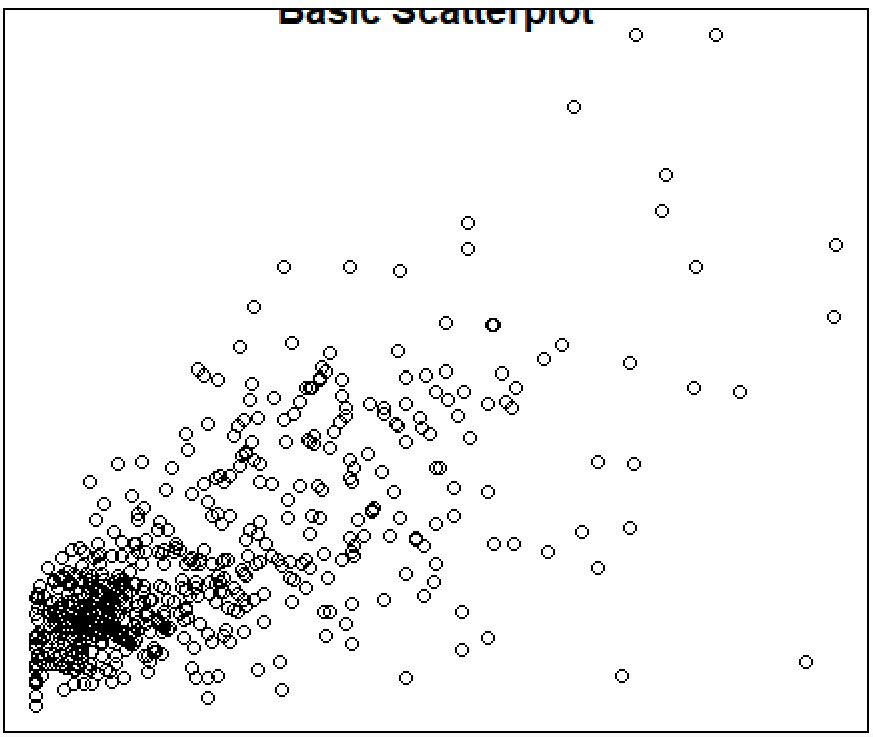
```
hist(CancerData$area_mean,
     main = 'Distribution of Cell Area Means',
     xlab = 'Mean Area',
     col = 'green')
```



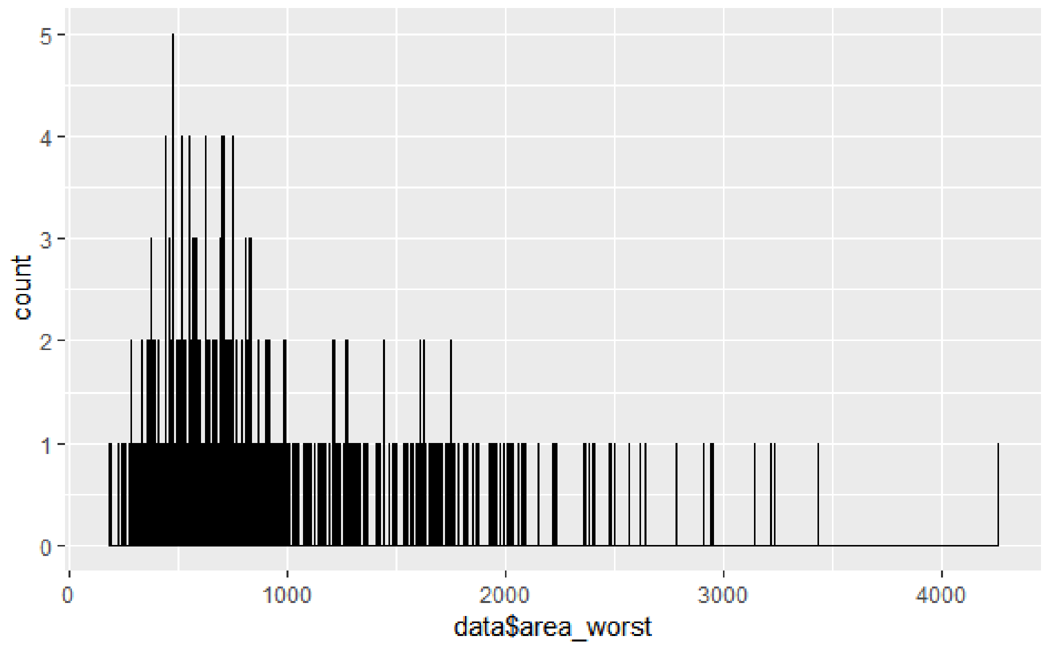
```
#we find that the data is imbalanced and also there is a lot of corelation
between the attributes
## we find that there are no missing values
## we find that data is little unbalanced
prop.table(table(data$diagnosis))

## 
##         B         M 
## 0.6274165 0.3725835

## we then show some correlation
corr_mat<-cor(data[,3:ncol(data)])
corrplot(corr_mat)
```



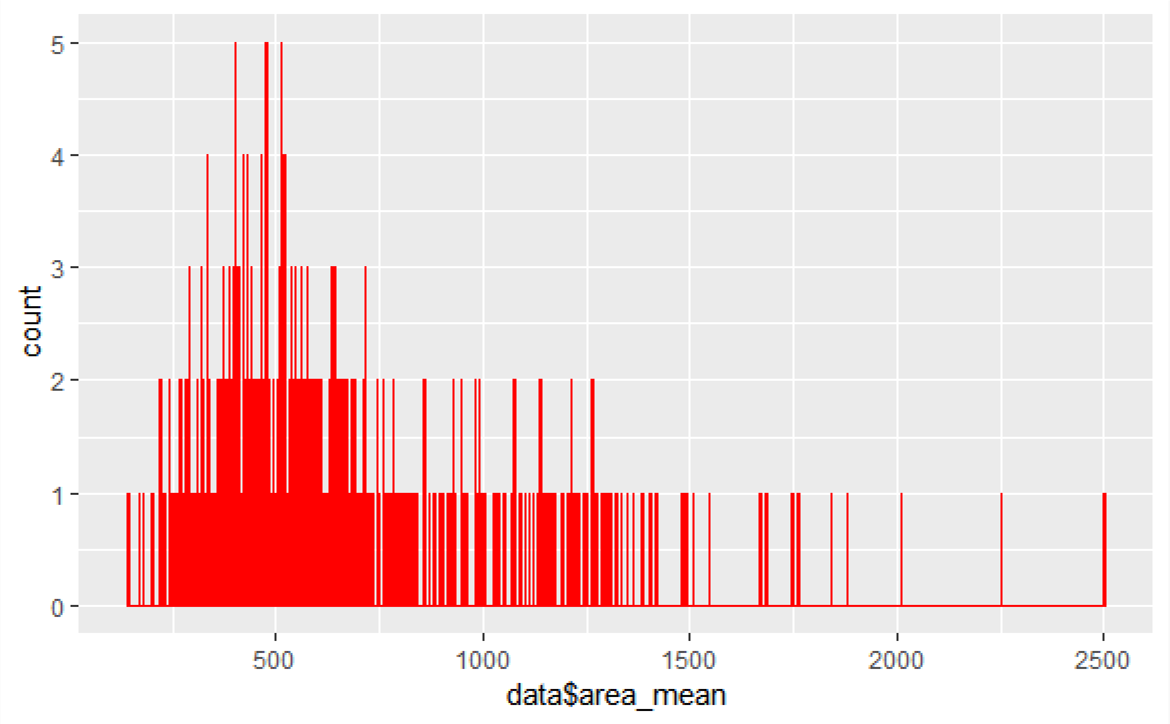
```
plot.new()

plot(data$area_mean ~data$concavity_mean)
title('Basic Scatterplot')
```



```
ggplot(data, aes(x=data$area_worst)) + geom_histogram(binwidth = 1, fill =
"yellow", color = "black")
```



```
ggplot(data, aes(x=data$area_mean)) + geom_histogram(binwidth = 1, fill =
"green", color = "red")
```



```
#Modelling
#We are going to get a training and a testing set to use when building some
models:
set.seed(1234)
data_index<-createDataPartition(data$diagnosis,p=0.75,list = FALSE)
train_data<-data[data_index,-1]
test_data<-data[data_index,-1]

## Applying learning models
fitControl <- trainControl(method="cv",
                           number = 5,
                           preProcOptions = list(thresh = 0.99), # threshold
for pca preprocess
                           classProbs = TRUE,
                           summaryFunction = twoClassSummary)
#Model1: Random Forest
#Building the model on the training data
## random forest
model_rf <- train(diagnosis~.,
                  train_data,
                  method="ranger",
                  metric="ROC",
                  #tuneLength=10,
                  #tuneGrid = expand.grid(mtry = c(2, 3, 6)),
                  preProcess = c('center', 'scale'),
                  trControl=fitControl)
```

```
#Testing on the testing data
## testing for random forets
pred_rf <- predict(model_rf, test_data)
cm_rf <- confusionMatrix(pred_rf, test_data$diagnosis, positive = "M")
cm_rf
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction   B   M
##          B 268   0
##          M   0 159
##
##                Accuracy : 1
##                  95% CI : (0.9914, 1)
##     No Information Rate : 0.6276
##     P-Value [Acc > NIR] : < 2.2e-16
##
##                   Kappa : 1
##  Mcnemar's Test P-Value : NA
##
##             Sensitivity : 1.0000
##             Specificity : 1.0000
##          Pos Pred Value : 1.0000
##          Neg Pred Value : 1.0000
##              Prevalence : 0.3724
##          Detection Rate : 0.3724
##    Detection Prevalence : 0.3724
##       Balanced Accuracy : 1.0000
##
##        'Positive' Class : M
##
```

```
# We find the accuracy of the model is 100%
#Random forest model- takes decision trees and averages them
normalize<-function(x){return((x-min(x))/(max(x)-min(x)))}
data$diagnosis<-as.numeric(data$diagnosis)
data_n<-as.data.frame(lapply(data,normalize))
traindata_n<--data_n[1:426,]
testdata_n<-data_n[427:569,]
rf <- randomForest(diagnosis ~., data= traindata_n, ntree =300, mtry = 5,
importance = TRUE)
```

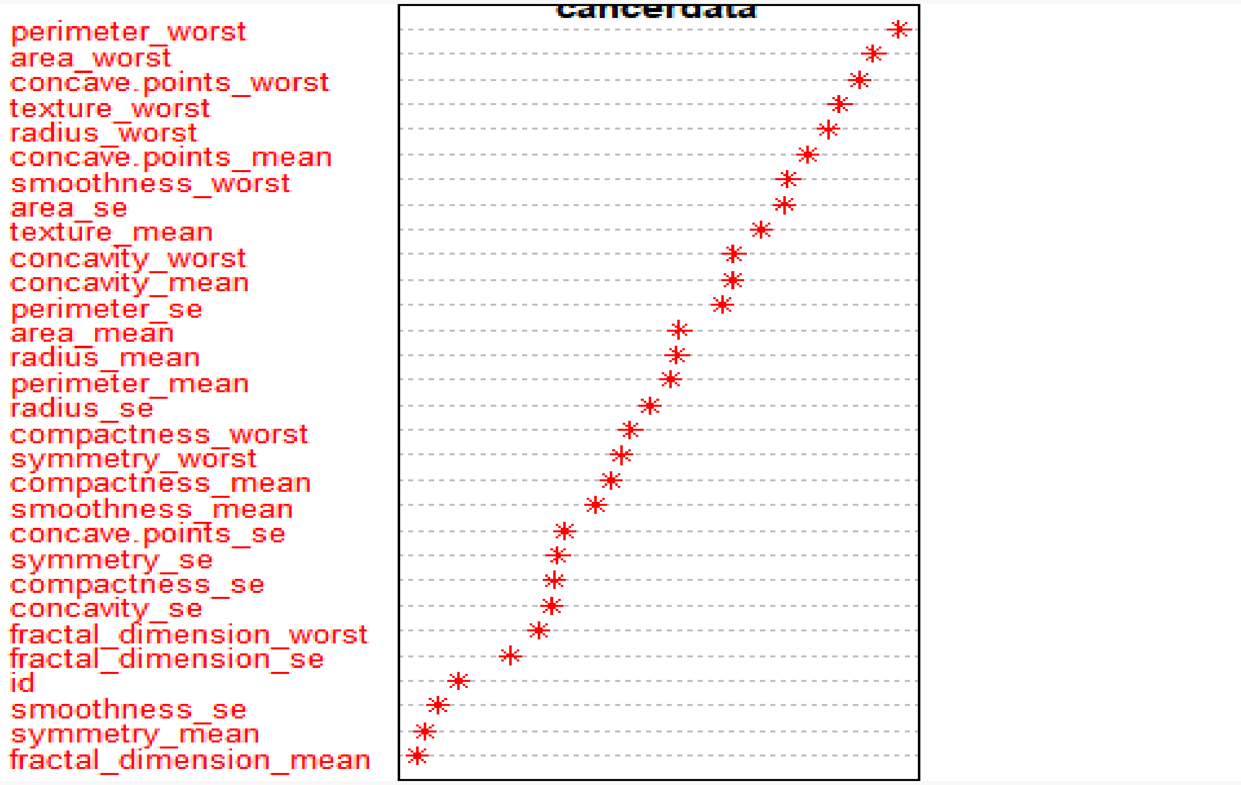
```
## Warning in randomForest.default(m, y, ...): The response has five or fewer
## unique values. Are you sure you want to do regression?
```

```
print(rf)
```

```
##
## Call:
##  randomForest(formula = diagnosis ~ ., data = traindata_n, ntree = 300,
mtry = 5, importance = TRUE)
##                Type of random forest: regression
##                      Number of trees: 300
## No. of variables tried at each split: 5
##
##           Mean of squared residuals: 0.03693862
##                     % Var explained: 84.79
```

```
plot.new()
```

```
varImpPlot(rf, type = 1, pch =8, col = 2, cex =0.8, main = "cancerdata")
abline(v= 45, col= "red")
```

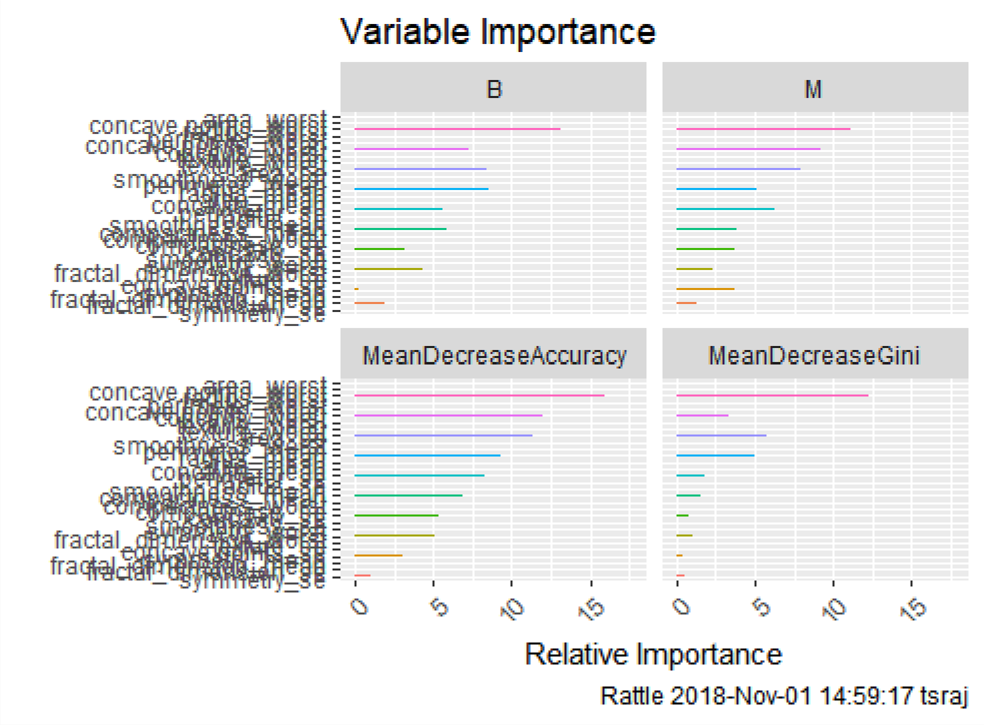


```
library(party)

## Loading required package: grid

## Loading required package: mvtnorm

## Loading required package: modeltools

## Loading required package: stats4

## Loading required package: strucchange

## Loading required package: zoo
```

```
##
## Attaching package: 'zoo'

## The following objects are masked from 'package:base':
##
##     as.Date, as.Date.numeric

## Loading required package: sandwich

#cf1 <- cforest(diagnosis ~ . , data=traindata_n ,
control=fitControl(mtry=5,ntree=300)) # fit the random forest

#varimp(cf1) # get variable importance, based on mean decrease in accuracy

#varimp(cf1, conditional=TRUE)  # conditional=True, adjusts for correlations
between predictors

#varimpAUC(cf1)  # more robust towards class imbalance.
```

	B	M	MeanDecreaseAccuracy	MeanDecreaseGini
area_worst	15.13	10.84	17.79	13.78
concave.points_worst	13.84	11.08	17.58	12.86
radius_worst	13.19	11.08	15.99	12.32
perimeter_worst	13.16	10.67	15.65	14.85
concave.points_mean	9.53	10.94	13.77	13.81
concavity_worst	7.32	9.27	11.99	3.33
texture_mean	8.28	9.79	11.95	2.10
texture_worst	8.63	10.24	11.74	2.30
area_se	8.40	7.98	11.33	5.83
smoothness_worst	6.42	8.05	10.23	1.57
perimeter_mean	8.58	5.62	9.60	7.04
radius_mean	8.55	5.14	9.37	4.99
area_mean	8.50	5.28	9.30	4.07
concavity_mean	5.31	6.54	9.03	3.90
perimeter_se	5.63	6.26	8.33	1.88

radius_se	5.66	4.59	7.60	1.23
smoothness_mean	4.07	6.30	7.34	0.92
compactness_mean	5.84	3.89	6.92	1.51
compactness_worst	4.29	4.11	6.37	1.44
compactness_se	4.34	2.83	5.35	0.59
concavity_se	3.20	3.77	5.33	0.76
smoothness_se	3.65	3.47	5.30	0.58
symmetry_worst	3.45	4.67	5.15	1.17
fractal_dimension_worst	4.31	2.39	5.05	1.06
texture_se	3.97	1.92	4.44	0.55
concave.points_se	3.70	2.72	4.39	0.51
symmetry_mean	0.22	3.69	3.03	0.45
fractal_dimension_mean	2.10	1.25	2.57	0.43
fractal_dimension_se	1.96	1.34	2.56	0.64
symmetry_se	0.96	0.48	1.03	0.55



Rattle 2018-Nov-01 14:59:17 tsraj

```
library(Boruta)

## Loading required package: ranger

##
## Attaching package: 'ranger'

## The following object is masked from 'package:rattle':
##
##     importance

## The following object is masked from 'package:randomForest':
##
##     importance

# Decide if a variable is important or not using Boruta

boruta_output <- Boruta( diagnosis~ ., data=na.omit(train_data), doTrace=2)
# perform Boruta search

##  1. run of importance source...

##  2. run of importance source...

##  3. run of importance source...

##  4. run of importance source...

##  5. run of importance source...
##  6. run of importance source...
##  7. run of importance source...
##  8. run of importance source...
##  9. run of importance source...
##  10. run of importance source...
##  11. run of importance source...
##  12. run of importance source...
## After 12 iterations, +3 secs:
##  confirmed 23 attributes: `concave points_mean`, `concave points_se`,
`concave points_worst`, area_mean, area_se and 18 more;
##  still have 7 attributes left.
##  13. run of importance source...
##  14. run of importance source...
##  15. run of importance source...
##  16. run of importance source...
##  17. run of importance source...
##  18. run of importance source...
##  19. run of importance source...
##  20. run of importance source...
##  21. run of importance source...
##  22. run of importance source...
##  23. run of importance source...
##  24. run of importance source...
##  25. run of importance source...
##  26. run of importance source...
##  27. run of importance source...
##  28. run of importance source...
##  29. run of importance source...
##  30. run of importance source...
##  31. run of importance source...
##  32. run of importance source...
##  33. run of importance source...
##  34. run of importance source...
##  35. run of importance source...
## After 35 iterations, +8.9 secs:
##  confirmed 1 attribute: compactness_se;
##  still have 6 attributes left.
##  36. run of importance source...
##  37. run of importance source...
##  38. run of importance source...
## After 38 iterations, +9.7 secs:
##  rejected 1 attribute: symmetry_se;
##  still have 5 attributes left.
##  39. run of importance source...
##  40. run of importance source...
##  41. run of importance source...
## After 41 iterations, +10 secs:
##  confirmed 1 attribute: symmetry_mean;
##  rejected 1 attribute: smoothness_se;
##  still have 3 attributes left.
##  42. run of importance source...
##  43. run of importance source...
## After 43 iterations, +11 secs:
##  confirmed 1 attribute: fractal_dimension_mean;
##  still have 2 attributes left.
##  44. run of importance source...
##  45. run of importance source...
##  46. run of importance source...
##  47. run of importance source...
##  48. run of importance source...
##  49. run of importance source...
##  50. run of importance source...
##  51. run of importance source...
##  52. run of importance source...
##  53. run of importance source...
##  54. run of importance source...
##  55. run of importance source...
##  56. run of importance source...
##  57. run of importance source...
##  58. run of importance source...
##  59. run of importance source...
##  60. run of importance source...
##  61. run of importance source...
##  62. run of importance source...
##  63. run of importance source...
##  64. run of importance source...
##  65. run of importance source...
##  66. run of importance source...
##  67. run of importance source...
##  68. run of importance source...
##  69. run of importance source...
## After 69 iterations, +17 secs:
##  confirmed 1 attribute: fractal_dimension_se;
##  still have 1 attribute left.
##  70. run of importance source...
##  71. run of importance source...

##  72. run of importance source...

##  73. run of importance source...

##  74. run of importance source...

##  75. run of importance source...

##  76. run of importance source...

##  77. run of importance source...

## After 77 iterations, +19 secs:

##  rejected 1 attribute: texture_se;

##  no more attributes left.
```

```
boruta_signif <-
names(boruta_output$finalDecision[boruta_output$finalDecision %in%
c("Confirmed", "Tentative")])
boruta_signif
```

```
##  [1] "radius_mean"              "texture_mean"
##  [3] "perimeter_mean"           "area_mean"
##  [5] "smoothness_mean"          "compactness_mean"
##  [7] "concavity_mean"           "`concave points_mean`"
##  [9] "symmetry_mean"            "fractal_dimension_mean"
## [11] "radius_se"                "perimeter_se"
## [13] "area_se"                  "compactness_se"
## [15] "concavity_se"             "`concave points_se`"
## [17] "fractal_dimension_se"     "radius_worst"
## [19] "texture_worst"            "perimeter_worst"
## [21] "area_worst"               "smoothness_worst"
## [23] "compactness_worst"        "concavity_worst"
## [25] "`concave points_worst`"   "symmetry_worst"
## [27] "fractal_dimension_worst"
```

```
#Model2: Naive Bayes
#Building and testing the model
model_nb <- train(diagnosis~.,
                  train_data,
                  method="nb",
                  metric="ROC",
                  preProcess=c('center', 'scale'),
                  trace=FALSE,
                  trControl=fitControl)

cm_nb <- confusionMatrix(pred_nb, test_data$diagnosis, positive = "M")
cm_nb
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction   B   M
##          B 259  17
##          M   9 142
##
##                Accuracy : 0.9391
##                  95% CI : (0.9121, 0.9598)
##     No Information Rate : 0.6276
##     P-Value [Acc > NIR] : <2e-16
##
##                   Kappa : 0.8684
##  Mcnemar's Test P-Value : 0.1698
##
##             Sensitivity : 0.8931
##             Specificity : 0.9664
##          Pos Pred Value : 0.9404
##          Neg Pred Value : 0.9384
##              Prevalence : 0.3724
##          Detection Rate : 0.3326
##    Detection Prevalence : 0.3536
##       Balanced Accuracy : 0.9297
##
##        'Positive' Class : M
##
```

```r
#Accuracy of the model is 93.9%
#Model3: glm
#Building and testing the model
model_glm <- train(diagnosis~.,
                  train_data,
                  method="glm",
                  metric="ROC",
                  preProcess=c('center', 'scale'),
                  trace=FALSE,
                  trControl=fitControl)



## predicting for test data
pred_glm <- predict(model_glm, test_data)
cm_glm <- confusionMatrix(pred_glm, test_data$diagnosis, positive = "M")
cm_glm
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction   B   M
##          B 265   4
##          M   3 155
```

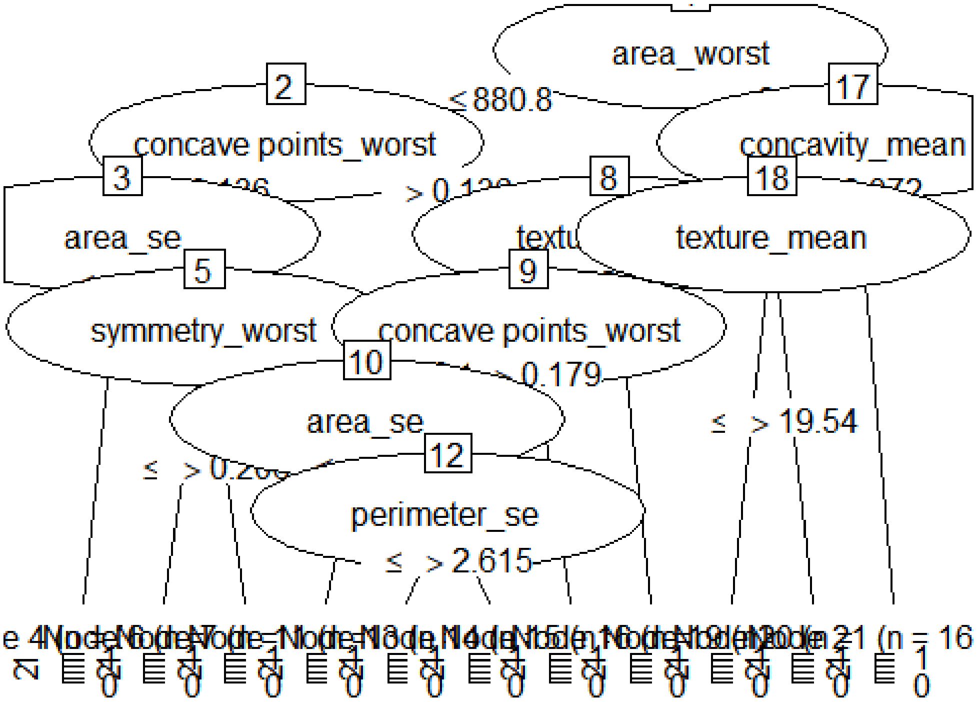
```
##
##                 Accuracy : 0.9836
##                   95% CI : (0.9665, 0.9934)
##      No Information Rate : 0.6276
##      P-Value [Acc > NIR] : <2e-16
##
##                    Kappa : 0.9649
##   Mcnemar's Test P-Value : 1
##
##              Sensitivity : 0.9748
##              Specificity : 0.9888
##           Pos Pred Value : 0.9810
##           Neg Pred Value : 0.9851
##               Prevalence : 0.3724
##           Detection Rate : 0.3630
##     Detection Prevalence : 0.3700
##        Balanced Accuracy : 0.9818
##
##         'Positive' Class : M
##
```

```r
#Accuracy of the model is 98.3%
#algorithm for decision tree
library(C50)
data$diagnosis<-as.factor(data$diagnosis)
tree <- C5.0( diagnosis~., data = data)
summary(tree)
```

```
##
## Call:
## C5.0.formula(formula = diagnosis ~ ., data = data)
##
##
## C5.0 [Release 2.07 GPL Edition]      Sat Nov 03 17:35:50 2018
## -------------------------------
##
## Class specified by attribute `outcome'
##
## Read 569 cases (32 attributes) from undefined.data
##
## Decision tree:
##
## area_worst > 880.8:
## :...concavity_mean > 0.0716: 2 (164)
## :   concavity_mean <= 0.0716:
## :   :...texture_mean <= 19.54: 1 (9/1)
## :       texture_mean > 19.54: 2 (10)
## area_worst <= 880.8:
## :...concave points_worst <= 0.1357:
##     :...area_se <= 36.46: 1 (319/3)
##     :   area_se > 36.46:
##     :   :...symmetry_worst <= 0.206: 2 (2)
##     :       symmetry_worst > 0.206: 1 (16/2)
##     concave points_worst > 0.1357:
##     :...texture_worst > 27.37: 2 (21)
##         texture_worst <= 27.37:
##         :...concave points_worst > 0.1789: 2 (4)
##             concave points_worst <= 0.1789:
##             :...area_se <= 21.91: 1 (12)
##                 area_se > 21.91:
##                 :...perimeter_se <= 2.615: 2 (6/1)
##                     perimeter_se > 2.615: 1 (6)
##
##
## Evaluation on training data (569 cases):
##
##      Decision Tree
##    ----------------
##    Size      Errors
##
##      11    7( 1.2%)   <<
##
##
##     (a)   (b)    <-classified as
##    ----  ----
##     356     1    (a): class 1
##       6   206    (b): class 2
##
##
##  Attribute usage:
##
##  100.00% area_worst
##   67.84% concave points_worst
##   63.44% area_se
##   32.16% concavity_mean
##    8.61% texture_worst
##    3.34% texture_mean
##    3.16% symmetry_worst
##    2.11% perimeter_se
##
##
## Time: 0.0 secs
```

```
plot.new()
```

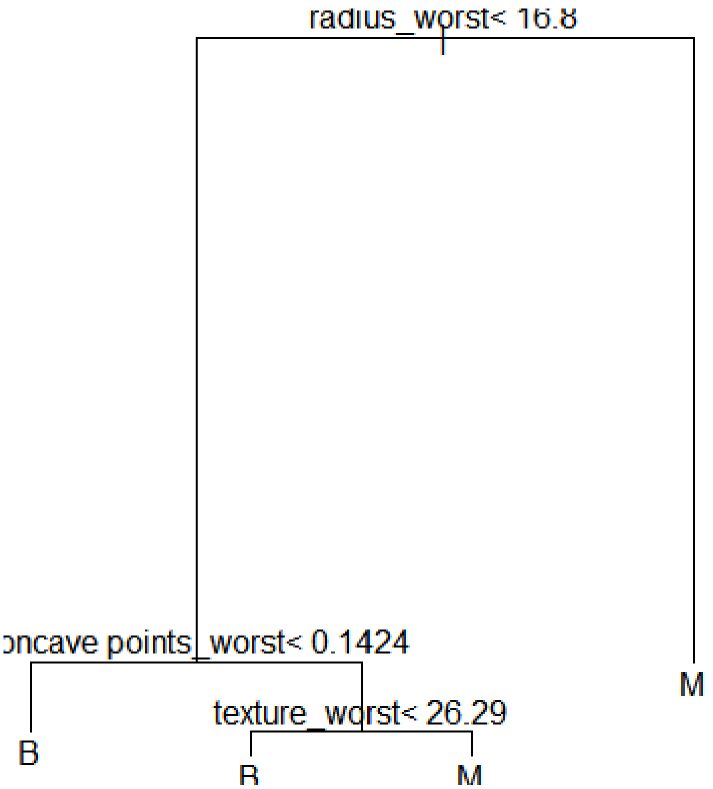
```
plot(tree)
```



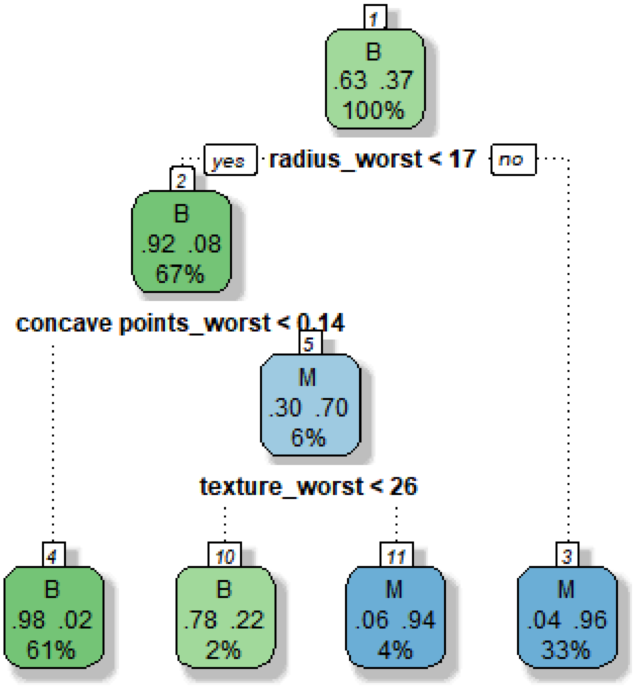
```
results <- C5.0(diagnosis ~., data = data, rules = TRUE)
summary(results)

##
## Call:
## C5.0.formula(formula = diagnosis ~ ., data = data, rules = TRUE)
##
##
## C5.0 [Release 2.07 GPL Edition]      Sat Nov 03 17:35:51 2018
## -------------------------------
##
## Class specified by attribute `outcome'
##
## Read 569 cases (32 attributes) from undefined.data
##
## Rules:
##
## Rule 1: (223/2, lift 1.6)
##  texture_mean <= 19.54
##  concavity_mean <= 0.0716
##  ->  class 1  [0.987]
##
## Rule 2: (386/37, lift 1.4)
##  area_worst <= 880.8
##  ->  class 1  [0.902]
##
## Rule 3: (164, lift 2.7)
##  concavity_mean > 0.0716
##  area_worst > 880.8
##  ->  class 2  [0.994]
##
## Rule 4: (126, lift 2.7)
##  texture_mean > 19.54
##  area_worst > 880.8
##  ->  class 2  [0.992]
##
## Rule 5: (109, lift 2.7)
##  concave points_worst > 0.1789
##  ->  class 2  [0.991]
##
## Rule 6: (114, lift 2.7)
##  texture_worst > 27.37
##  concave points_worst > 0.1357
##  ->  class 2  [0.991]
##
## Default class: 1
##
##
## Evaluation on training data (569 cases):
##
##          Rules
##    ----------------
##      No      Errors
##
##       6   13( 2.3%)   <<
##
##
##     (a)   (b)    <-classified as
##    ----  ----
##     357          (a): class 1
##      13   199    (b): class 2
##
##
##  Attribute usage:
##
##   98.42% area_worst
##   68.01% concavity_mean
##   61.34% texture_mean
##   26.89% concave points_worst
##   20.04% texture_worst
##
##
## Time: 0.0 secs
```

```
data<-as.data.frame(data)
library(rpart)
tree<-rpart(diagnosis~.,data =train_data,method="class")
```

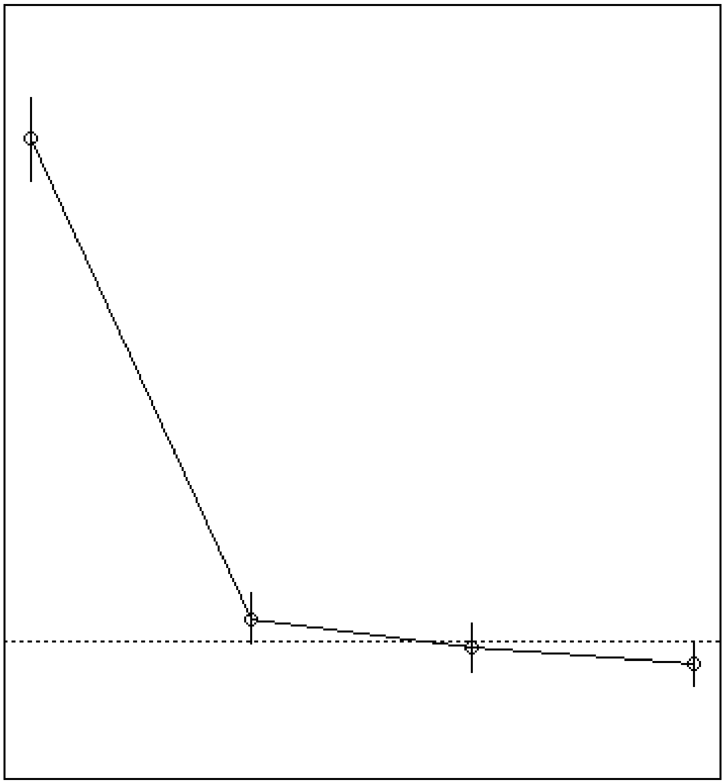
```r
plot(tree)
text(tree, pretty=0)
library(rattle)
library(rpart.plot)
library(RColorBrewer)
plot.new()
```



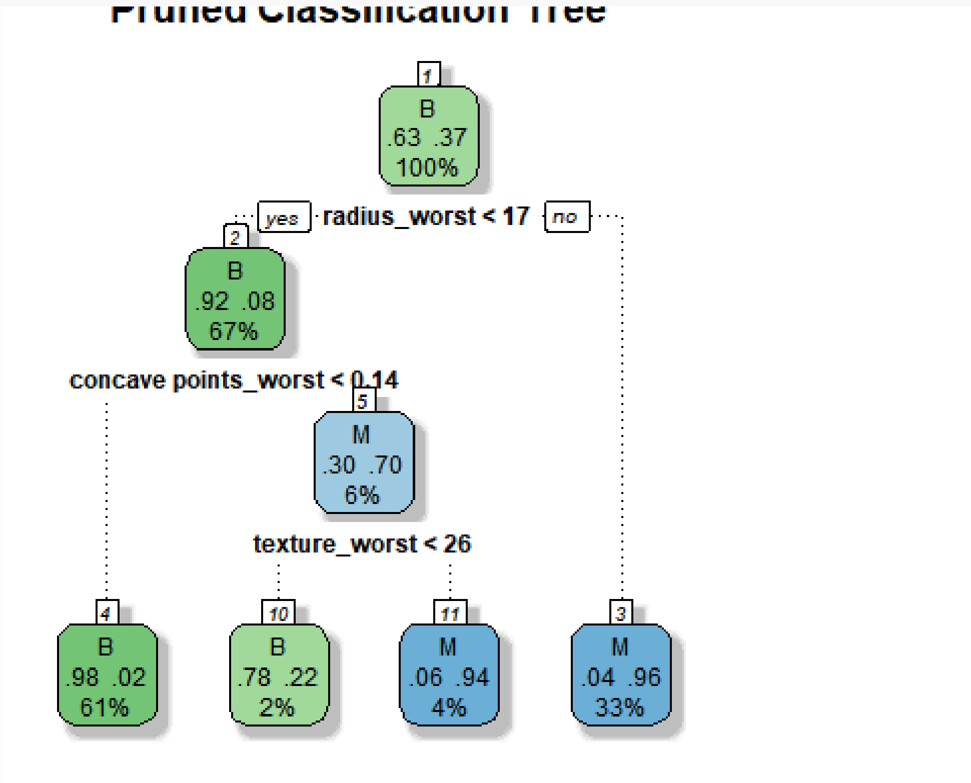
```r
fancyRpartPlot(tree)
plot.new()
```



```
printcp(tree)

##
## Classification tree:
## rpart(formula = diagnosis ~ ., data = train_data, method = "class")
##
## Variables actually used in tree construction:
## [1] concave points_worst radius_worst         texture_worst
##
## Root node error: 159/427 = 0.37237
##
## n= 427
##
##          CP nsplit rel error  xerror     xstd
## 1 0.811321      0   1.00000 1.00000 0.062828
## 2 0.069182      1   0.18868 0.26415 0.038703
## 3 0.031447      2   0.11950 0.22013 0.035651
## 4 0.010000      3   0.08805 0.19497 0.033722

plotcp(tree)
ptree<- prune(tree, cp=
tree$cptable[which.min(tree$cptable[,"xerror"]),"CP"])
plot.new()
```



```
fancyRpartPlot(ptree, uniform=TRUE,main="Pruned Classification Tree")
```



```
library(rpart)
```

```
fit1 <- rpart(diagnosis~.,data=train_data)
fit1
```

```
## n= 427
##
## node), split, n, loss, yval, (yprob)
##       * denotes terminal node
##
##  1) root 427 159 B (0.62763466 0.37236534)
##    2) radius_worst< 16.795 286  24 B (0.91608392 0.08391608)
##      4) concave points_worst< 0.14235 259   5 B (0.98069498 0.01930502) *
##      5) concave points_worst>=0.14235 27   8 M (0.29629630 0.70370370)
##       10) texture_worst< 26.285 9   2 B (0.77777778 0.22222222) *
##       11) texture_worst>=26.285 18   1 M (0.05555556 0.94444444) *
##    3) radius_worst>=16.795 141   6 M (0.04255319 0.95744681) *
```

```
summary(fit1)
```

```
## Call:
## rpart(formula = diagnosis ~ ., data = train_data)
##   n= 427
##
##           CP nsplit  rel error    xerror       xstd
## 1 0.81132075      0 1.00000000 1.0000000 0.06282824
## 2 0.06918239      1 0.18867925 0.2201258 0.03565053
## 3 0.03144654      2 0.11949686 0.1635220 0.03107762
## 4 0.01000000      3 0.08805031 0.1823899 0.03269862
##
## Variable importance
##         radius_worst            area_worst       perimeter_worst
##                   16                    16                    15
##            area_mean           radius_mean        perimeter_mean
##                   14                    14                    14
## concave points_worst       concavity_worst        concavity_mean
##                    3                     2                     1
##    compactness_worst   concave points_mean      compactness_mean
##                    1                     1                     1
##        texture_worst
##                    1
##
## Node number 1: 427 observations,    complexity param=0.8113208
##   predicted class=B  expected loss=0.3723653  P(node) =1
##     class counts:   268   159
##    probabilities: 0.628 0.372
##   left son=2 (286 obs) right son=3 (141 obs)
##   Primary splits:
##       radius_worst         < 16.795   to the left,  improve=144.1264, (0
missing)
##       perimeter_worst      < 112.6    to the left,  improve=143.9985, (0
missing)
```

```
##       area_worst           < 884.55   to the left,  improve=140.9804, (0
missing)
##       concave points_worst < 0.14235  to the left,  improve=138.8752, (0
missing)
##       concave points_mean  < 0.05593  to the left,  improve=132.0683, (0
missing)
##   Surrogate splits:
##       area_worst      < 868.2    to the left,  agree=0.993, adj=0.979, (0
split)
##       perimeter_worst < 111.7    to the left,  agree=0.974, adj=0.922, (0
split)
##       area_mean       < 697.8    to the left,  agree=0.960, adj=0.879, (0
split)
##       radius_mean     < 15.045   to the left,  agree=0.958, adj=0.872, (0
split)
##       perimeter_mean  < 96.405   to the left,  agree=0.946, adj=0.837, (0
split)
##
## Node number 2: 286 observations,    complexity param=0.06918239
##   predicted class=B  expected loss=0.08391608  P(node) =0.6697892
##     class counts:   262    24
##    probabilities: 0.916 0.084
##   left son=4 (259 obs) right son=5 (27 obs)
##   Primary splits:
##       concave points_worst < 0.14235  to the left,  improve=22.90582, (0
missing)
##       concavity_mean       < 0.11865  to the left,  improve=19.46751, (0
missing)
##       concavity_worst      < 0.3782   to the left,  improve=19.39395, (0
missing)
##       compactness_worst    < 0.3849   to the left,  improve=17.79391, (0
missing)
##       concave points_mean  < 0.05593  to the left,  improve=17.40573, (0
missing)
##   Surrogate splits:
##       concavity_worst     < 0.4383   to the left,  agree=0.969, adj=0.667,
(0 split)
##       compactness_worst   < 0.3849   to the left,  agree=0.955, adj=0.519,
(0 split)
##       concavity_mean      < 0.1563   to the left,  agree=0.951, adj=0.481,
(0 split)
##       concave points_mean < 0.06687  to the left,  agree=0.948, adj=0.444,
(0 split)
##       compactness_mean    < 0.15     to the left,  agree=0.937, adj=0.333,
(0 split)
##
## Node number 3: 141 observations
##   predicted class=M  expected loss=0.04255319  P(node) =0.3302108
##     class counts:     6   135
##    probabilities: 0.043 0.957
```

```
##
## Node number 4: 259 observations
##   predicted class=B  expected loss=0.01930502  P(node) =0.6065574
##     class counts:   254     5
##    probabilities: 0.981 0.019
##
## Node number 5: 27 observations,    complexity param=0.03144654
##   predicted class=M  expected loss=0.2962963  P(node) =0.06323185
##     class counts:     8    19
##    probabilities: 0.296 0.704
##   left son=10 (9 obs) right son=11 (18 obs)
##   Primary splits:
##       texture_worst        < 26.285   to the left,  improve=6.259259, (0
missing)
##       smoothness_worst     < 0.1405   to the left,  improve=4.680312, (0
missing)
##       smoothness_mean      < 0.1083   to the left,  improve=4.402116, (0
missing)
##       texture_mean         < 20.3     to the left,  improve=3.792593, (0
missing)
##       concave points_worst < 0.17175  to the left,  improve=3.792593, (0
missing)
##   Surrogate splits:
##       texture_mean     < 16.22    to the left,  agree=0.852, adj=0.556, (0
split)
##       smoothness_worst < 0.13145  to the left,  agree=0.815, adj=0.444, (0
split)
##       concavity_mean   < 0.089375 to the left,  agree=0.778, adj=0.333, (0
split)
##       smoothness_se    < 0.005373 to the left,  agree=0.778, adj=0.333, (0
split)
##       concavity_se     < 0.11138  to the right, agree=0.778, adj=0.333, (0
split)
##
## Node number 10: 9 observations
##   predicted class=B  expected loss=0.2222222  P(node) =0.02107728
##     class counts:     7     2
##    probabilities: 0.778 0.222
##
## Node number 11: 18 observations
##   predicted class=M  expected loss=0.05555556  P(node) =0.04215457
##     class counts:     1    17
##    probabilities: 0.056 0.944
```

```
#Kernlab Classification
require(kernlab)
```

```
## Loading required package: kernlab
```

```
##
## Attaching package: 'kernlab'

## The following object is masked from 'package:modeltools':
##
##     prior

## The following object is masked from 'package:ggplot2':
##
##     alpha

installed.packages("kernlab")

##      Package LibPath Version Priority Depends Imports LinkingTo Suggests
##      Enhances License License_is_FOSS License_restricts_use OS_type Archs
##      MD5sum NeedsCompilation Built

library(kernlab)
data_classifier<-ksvm(diagnosis ~., data =train_data , kernel='vanilladot')

##  Setting default kernel parameters

data_classifier

## Support Vector Machine object of class "ksvm"
##
## SV type: C-svc  (classification)
##  parameter : cost C = 1
##
## Linear (vanilla) kernel function.
##
## Number of Support Vectors : 28
##
## Objective Function Value : -13.7674
## Training error : 0.007026

data_predictions<-predict(data_classifier,test_data)
head(data_predictions)

## [1] M M M M M M
## Levels: B M

table(data_predictions, test_data$diagnosis)

##
## data_predictions   B   M
##                B 267   2
##                M   1 157

agreement<-data_predictions == test_data$diagnosis
table(agreement)
```

```
## agreement
## FALSE  TRUE 
##     3   424
```

```
prop.table(table(agreement))
```

```
## agreement
##       FALSE        TRUE 
## 0.007025761 0.992974239
```

```
Agreement
```

```
##   [1]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [12]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [23]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [34]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [45]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE  TRUE  TRUE
##  [56]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [67]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [78]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
##  [89]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE FALSE  TRUE
## [100]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [111]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [122]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [133]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [144]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [155]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [166]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [177] FALSE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [188]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [199]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [210]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [221]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [232]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [243]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [254]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [265]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [276]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [287]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [298]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [309]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [320]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [331]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [342]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [353]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [364]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [375]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [386]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [397]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [408]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
## [419]  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE  TRUE
```

```
set.seed(12345)
data_classifier_rbf<-ksvm(diagnosis ~., data = train_data, kernel='rbfdot')
data_predictions_rbf<-predict(data_classifier_rbf,test_data)
agreement_rbf<-data_predictions_rbf == test_data$diagnosis
table(agreement_rbf)
```

```
## agreement_rbf
## FALSE  TRUE
##     2   425
```

```
prop.table(table(agreement_rbf))
```

```
## agreement_rbf
##       FALSE        TRUE
## 0.004683841 0.995316159
```

```
# logistic regression model:
fit <- glm(diagnosis~.,data = train_data,family = binomial(link='logit'))
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
summary(fit)
```

```
##
## Call:
## glm(formula = diagnosis ~ ., family = binomial(link = "logit"),
##     data = train_data)
##
## Deviance Residuals:
##    Min      1Q  Median      3Q     Max
##  -8.49    0.00    0.00    0.00    8.49
##
## Coefficients:
##                          Estimate Std. Error   z value Pr(>|z|)
## (Intercept)             -5.487e+15  1.418e+08 -38703923   <2e-16 ***
## radius_mean             -1.401e+13  5.949e+07   -235423   <2e-16 ***
## texture_mean            -5.783e+13  2.594e+06 -22293459   <2e-16 ***
## perimeter_mean          -1.954e+14  8.518e+06 -22935779   <2e-16 ***
## area_mean                7.231e+12  1.723e+05  41962794   <2e-16 ***
## smoothness_mean          1.141e+16  6.970e+08  16374586   <2e-16 ***
## compactness_mean        -1.560e+16  4.601e+08 -33898361   <2e-16 ***
## concavity_mean           3.612e+15  3.663e+08   9859481   <2e-16 ***
## `concave points_mean`    3.368e+16  6.496e+08  51839897   <2e-16 ***
## symmetry_mean            7.166e+14  2.485e+08   2883416   <2e-16 ***
## fractal_dimension_mean  -1.875e+16  1.853e+09 -10119625   <2e-16 ***
## radius_se               -1.780e+14  1.147e+08  -1552350   <2e-16 ***
## texture_se              -5.141e+14  1.143e+07 -44982769   <2e-16 ***
## perimeter_se            -1.506e+14  1.516e+07  -9929607   <2e-16 ***
## area_se                  3.909e+12  4.713e+05   8294154   <2e-16 ***
## smoothness_se            6.741e+16  2.230e+09  30224242   <2e-16 ***
## compactness_se          -1.263e+16  7.957e+08 -15868906   <2e-16 ***
## concavity_se            -6.112e+15  4.465e+08 -13688233   <2e-16 ***
## `concave points_se`      2.479e+16  1.882e+09  13170418   <2e-16 ***
## symmetry_se              3.309e+16  8.953e+08  36963236   <2e-16 ***
## fractal_dimension_se     2.482e+16  4.032e+09   6155984   <2e-16 ***
## radius_worst             7.751e+14  2.067e+07  37495454   <2e-16 ***
## texture_worst            1.151e+14  2.192e+06  52500738   <2e-16 ***
## perimeter_worst          7.806e+13  2.049e+06  38088467   <2e-16 ***
## area_worst              -5.352e+12  1.108e+05 -48313624   <2e-16 ***
## smoothness_worst        -4.364e+15  4.930e+08  -8850467   <2e-16 ***
## compactness_worst        1.527e+15  1.306e+08  11684310   <2e-16 ***
## concavity_worst          2.629e+15  9.403e+07  27964084   <2e-16 ***
## `concave points_worst`  -5.585e+15  3.231e+08 -17282850   <2e-16 ***
## symmetry_worst          -1.380e+15  1.615e+08  -8543749   <2e-16 ***
## fractal_dimension_worst  8.968e+15  7.758e+08  11560246   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 563.81  on 426  degrees of freedom
## Residual deviance: 504.61  on 396  degrees of freedom
## AIC: 566.61
##
## Number of Fisher Scoring iterations: 19
```

```
library(MASS)
step_fit <- stepAIC(fit,method='backward')
```

```
## Start:  AIC=566.61
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean + 
##     smoothness_mean + compactness_mean + concavity_mean + `concave 
points_mean` + 
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se + 
##     perimeter_se + area_se + smoothness_se + compactness_se + 
##     concavity_se + `concave points_se` + symmetry_se + 
fractal_dimension_se + 
##     radius_worst + texture_worst + perimeter_worst + area_worst + 
##     smoothness_worst + compactness_worst + concavity_worst + 
##     `concave points_worst` + symmetry_worst + fractal_dimension_worst
```

```
##                             Df Deviance    AIC
## - perimeter_se               1     0.00  60.00
## - area_mean                  1     0.00  60.00
## - radius_mean                1     0.00  60.00
## - area_se                    1     0.00  60.00
## - symmetry_se                1     0.00  60.00
## - radius_worst               1     0.00  60.00
## - radius_se                  1     0.00  60.00
## - texture_mean             1     0.00  60.00
## - smoothness_worst         1     0.00  60.00
## - compactness_mean         1     0.00  60.00
## - area_worst               1     0.00  60.00
## - smoothness_mean          1     0.00  60.00
## - compactness_se           1     0.00  60.00
## - `concave points_se`      1     0.00  60.00
## - perimeter_worst          1     0.00  60.00
## - compactness_worst        1     0.00  60.00
## - concavity_se             1     0.00  60.00
## - `concave points_mean`    1     0.00  60.00
## - smoothness_se            1     0.00  60.00
## - symmetry_mean            1     0.00  60.00
## - `concave points_worst`   1     0.00  60.00
## - symmetry_worst           1     0.00  60.00
## - fractal_dimension_mean   1     0.00  60.00
## - fractal_dimension_se     1     0.00  60.00
## - texture_se               1     0.00  60.00
## - perimeter_mean           1     0.00  60.00
## - fractal_dimension_worst  1     0.00  60.00
## - texture_worst            1     0.00  60.00
## - concavity_mean           1     0.00  60.00
## - concavity_worst          1     0.00  60.00
## <none>                         504.61 566.61

## Warning: glm.fit: algorithm did not converge

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=60
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     smoothness_mean + compactness_mean + concavity_mean + `concave
points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + compactness_se + concavity_se +
##     `concave points_se` + symmetry_se + fractal_dimension_se +
##     radius_worst + texture_worst + perimeter_worst + area_worst +
##     smoothness_worst + compactness_worst + concavity_worst +
##     `concave points_worst` + symmetry_worst + fractal_dimension_worst

##                            Df   Deviance AIC
## - symmetry_worst            1 8.1185e-08  58
## - smoothness_mean           1 8.1328e-08  58
## - radius_mean               1 8.1330e-08  58
## - symmetry_se               1 8.1384e-08  58
## - perimeter_mean            1 8.1412e-08  58
## - concavity_mean            1 8.1488e-08  58
## - fractal_dimension_mean    1 8.1635e-08  58
## - concavity_worst           1 8.1665e-08  58
## - area_se                  1 8.1827e-08  58
## - area_mean                1 8.1867e-08  58
## - smoothness_worst         1 8.2830e-08  58
## - radius_worst             1 8.2832e-08  58
## - texture_mean             1 8.3132e-08  58
## - area_worst               1 8.3541e-08  58
## - radius_se                1 8.3657e-08  58
## - texture_se               1 8.4696e-08  58
## - compactness_se           1 8.4708e-08  58
## - `concave points_se`      1 8.4934e-08  58
## - `concave points_worst`   1 8.5490e-08  58
## - symmetry_mean            1 8.6407e-08  58
## - compactness_worst        1 8.6824e-08  58
## - smoothness_se            1 8.7001e-08  58
## - concavity_se             1 8.7224e-08  58
## - compactness_mean         1 8.9111e-08  58
## - perimeter_worst          1 9.3748e-08  58
## - `concave points_mean`    1 9.7167e-08  58
## - fractal_dimension_se     1 1.0211e-07  58
## - texture_worst            1 1.2312e-07  58
## - fractal_dimension_worst  1 1.2498e-07  58
## <none>                       8.1046e-08  60

##
## Step:  AIC=58
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean + 
##     smoothness_mean + compactness_mean + concavity_mean + `concave 
points_mean` + 
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se + 
##     area_se + smoothness_se + compactness_se + concavity_se + 
##     `concave points_se` + symmetry_se + fractal_dimension_se + 
##     radius_worst + texture_worst + perimeter_worst + area_worst + 
##     smoothness_worst + compactness_worst + concavity_worst + 
##     `concave points_worst` + fractal_dimension_worst

##                           Df   Deviance AIC
## - smoothness_mean          1 8.1503e-08  56
## - concavity_mean           1 8.1710e-08  56
## - area_mean                1 8.1904e-08  56
## - concavity_worst          1 8.1932e-08  56
## - area_se                  1 8.1989e-08  56
## - radius_mean              1 8.2183e-08  56
## - perimeter_mean           1 8.2263e-08  56
## - symmetry_se              1 8.2539e-08  56
## - fractal_dimension_mean   1 8.2652e-08  56
## - radius_worst             1 8.3116e-08  56
## - texture_mean             1 8.3594e-08  56
## - area_worst               1 8.3792e-08  56
## - radius_se                1 8.4234e-08  56
## - smoothness_worst         1 8.4388e-08  56
## - texture_se               1 8.5299e-08  56
## - compactness_se           1 8.5309e-08  56
## - `concave points_se`      1 8.6048e-08  56
## - concavity_se             1 8.7340e-08  56
## - `concave points_worst`   1 8.7440e-08  56
## - compactness_worst        1 8.7947e-08  56
## - symmetry_mean            1 8.9378e-08  56
## - smoothness_se            1 9.0366e-08  56
## - compactness_mean         1 9.0526e-08  56
## - perimeter_worst          1 1.0307e-07  56
## - fractal_dimension_se     1 1.0347e-07  56
## - `concave points_mean`    1 1.0610e-07  56
## - fractal_dimension_worst  1 1.1613e-07  56
## - texture_worst            1 1.3057e-07  56
## <none>                       8.1185e-08  58

##
## Step:  AIC=56
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + compactness_se + concavity_se +
##     `concave points_se` + symmetry_se + fractal_dimension_se +
##     radius_worst + texture_worst + perimeter_worst + area_worst +
##     smoothness_worst + compactness_worst + concavity_worst +
##     `concave points_worst` + fractal_dimension_worst

##                            Df   Deviance AIC
## - concavity_worst          1 8.2241e-08  54
## - concavity_mean           1 8.2344e-08  54
## - perimeter_mean           1 8.2473e-08  54
## - radius_mean              1 8.2570e-08  54
## - symmetry_se              1 8.2688e-08  54
## - area_mean                1 8.3433e-08  54
## - fractal_dimension_mean   1 8.3635e-08  54
## - area_se                  1 8.3636e-08  54
## - radius_worst             1 8.3745e-08  54
## - area_worst               1 8.4731e-08  54
## - compactness_se           1 8.5398e-08  54
## - texture_mean             1 8.5575e-08  54
## - radius_se                1 8.5625e-08  54
## - texture_se               1 8.5921e-08  54
## - `concave points_se`      1 8.7731e-08  54
## - smoothness_worst         1 8.7924e-08  54
## - compactness_worst        1 8.7985e-08  54
## - symmetry_mean            1 9.0013e-08  54
## - concavity_se             1 9.0401e-08  54
## - compactness_mean         1 9.1017e-08  54
## - smoothness_se            1 9.1332e-08  54
## - `concave points_worst`   1 9.1496e-08  54
## - fractal_dimension_se     1 1.0358e-07  54
## - perimeter_worst          1 1.0853e-07  54
## - `concave points_mean`    1 1.1045e-07  54
## - fractal_dimension_worst  1 1.1273e-07  54
## - texture_worst            1 1.3219e-07  54
## <none>                       8.1503e-08  56

##
## Step:  AIC=54
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + compactness_se + concavity_se +
##     `concave points_se` + symmetry_se + fractal_dimension_se +
##     radius_worst + texture_worst + perimeter_worst + area_worst +
##     smoothness_worst + compactness_worst + `concave points_worst` +
##     fractal_dimension_worst



##                           Df   Deviance AIC
## - symmetry_se              1 8.3042e-08  52
## - radius_worst             1 8.3582e-08  52
## - perimeter_mean           1 8.3733e-08  52
## - radius_mean              1 8.4489e-08  52
## - compactness_se           1 8.5639e-08  52
## - area_se                  1 8.5749e-08  52
## - area_worst               1 8.6048e-08  52
## - texture_mean             1 8.6272e-08  52
## - fractal_dimension_mean   1 8.6830e-08  52
## - radius_se                1 8.7124e-08  52
## - `concave points_se`      1 8.7824e-08  52
## - compactness_worst        1 8.7956e-08  52
## - texture_se               1 8.8696e-08  52
## - smoothness_worst         1 8.9126e-08  52
## - concavity_mean           1 8.9451e-08  52
## - smoothness_se            1 9.1712e-08  52
## - compactness_mean         1 9.1994e-08  52
## - area_mean                1 9.2627e-08  52
## - `concave points_worst`   1 9.2804e-08  52
## - concavity_se             1 9.6123e-08  52
## - symmetry_mean            1 9.7910e-08  52
## - fractal_dimension_se     1 1.0849e-07  52
## - `concave points_mean`    1 1.0954e-07  52
## - fractal_dimension_worst  1 1.1344e-07  52
## - perimeter_worst          1 1.2244e-07  52
## - texture_worst            1 1.6824e-07  52
## <none>                       8.2241e-08  54

## Step:  AIC=52
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + compactness_se + concavity_se +
##     `concave points_se` + fractal_dimension_se + radius_worst +
##     texture_worst + perimeter_worst + area_worst + smoothness_worst +
##     compactness_worst + `concave points_worst` + fractal_dimension_worst

##                          Df   Deviance AIC
## - radius_worst             1 8.3575e-08  50
## - area_se                  1 8.5568e-08  50
## - compactness_se           1 8.5576e-08  50
## - perimeter_mean           1 8.6771e-08  50
## - texture_mean             1 8.6950e-08  50
## - radius_se                1 8.7007e-08  50
## - radius_mean              1 8.7320e-08  50
## - `concave points_se`      1 8.7396e-08  50
## - area_worst               1 8.7536e-08  50
## - smoothness_worst         1 8.8966e-08  50
## - area_mean                1 9.2306e-08  50
## - texture_se               1 9.2709e-08  50
## - `concave points_worst`   1 9.2936e-08  50
## - compactness_worst        1 9.2986e-08  50
## - fractal_dimension_mean   1 9.4960e-08  50
## - concavity_mean           1 9.7411e-08  50
## - smoothness_se            1 9.7640e-08  50
## - concavity_se             1 9.8434e-08  50
## - compactness_mean         1 1.0148e-07  50
## - fractal_dimension_worst  1 1.2325e-07  50
## - `concave points_mean`    1 1.2837e-07  50
## - perimeter_worst          1 1.2904e-07  50
## - fractal_dimension_se     1 1.3028e-07  50
## - symmetry_mean            1 1.4516e-07  50
## - texture_worst            1 1.7117e-07  50
## <none>                       8.3042e-08  52

##
## Step:  AIC=50
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + compactness_se + concavity_se +
##     `concave points_se` + fractal_dimension_se + texture_worst +
##     perimeter_worst + area_worst + smoothness_worst + compactness_worst +
##     `concave points_worst` + fractal_dimension_worst

##                          Df   Deviance AIC
## - compactness_se           1 8.5992e-08  48
## - area_se                  1 8.6162e-08  48
## - texture_mean             1 8.7211e-08  48
## - radius_se                1 8.7920e-08  48
## - `concave points_se`      1 8.8100e-08  48
## - smoothness_worst         1 9.0500e-08  48
## - area_worst               1 9.1877e-08  48
## - `concave points_worst`   1 9.3927e-08  48
## - area_mean                1 9.5348e-08  48
## - fractal_dimension_mean   1 9.5713e-08  48
## - texture_se               1 9.7257e-08  48
## - concavity_mean           1 9.9576e-08  48
## - compactness_worst        1 1.0035e-07  48
## - concavity_se             1 1.0195e-07  48
## - perimeter_mean           1 1.0323e-07  48
## - compactness_mean         1 1.0358e-07  48
## - smoothness_se            1 1.0375e-07  48
## - radius_mean              1 1.0978e-07  48
## - fractal_dimension_se     1 1.3788e-07  48
## - `concave points_mean`    1 1.4162e-07  48
## - perimeter_worst          1 1.5232e-07  48
## - symmetry_mean            1 1.6084e-07  48
## - fractal_dimension_worst  1 1.6307e-07  48
## - texture_worst            1 1.7361e-07  48
## <none>                       8.3575e-08  50

##
## Step:  AIC=48
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     area_se + smoothness_se + concavity_se + `concave points_se` +
##     fractal_dimension_se + texture_worst + perimeter_worst +
##     area_worst + smoothness_worst + compactness_worst + `concave
points_worst` +
##     fractal_dimension_worst

##                           Df   Deviance AIC
## - area_se                  1 8.6642e-08  46
## - radius_se                1 8.7847e-08  46
## - texture_mean             1 8.7903e-08  46
## - `concave points_se`      1 9.0391e-08  46
## - smoothness_worst         1 9.2366e-08  46
## - area_worst               1 9.4740e-08  46
## - fractal_dimension_mean   1 9.4814e-08  46
## - `concave points_worst`   1 9.6245e-08  46
## - area_mean                1 9.7249e-08  46
## - texture_se               1 9.8732e-08  46
## - concavity_mean           1 1.0099e-07  46
## - concavity_se             1 1.0248e-07  46
## - compactness_mean         1 1.0308e-07  46
## - smoothness_se            1 1.0409e-07  46
## - compactness_worst        1 1.1529e-07  46
## - perimeter_mean           1 1.1614e-07  46
## - radius_mean              1 1.2106e-07  46
## - perimeter_worst          1 1.5568e-07  46
## - `concave points_mean`    1 1.5706e-07  46
## - symmetry_mean            1 1.7049e-07  46
## - texture_worst            1 1.7198e-07  46
## - fractal_dimension_se     1 2.0498e-07  46
## - fractal_dimension_worst  1 2.3012e-07  46
## <none>                       8.5992e-08  48

##
## Step:  AIC=46
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + radius_se + texture_se +
##     smoothness_se + concavity_se + `concave points_se` +
fractal_dimension_se +
##     texture_worst + perimeter_worst + area_worst + smoothness_worst +
##     compactness_worst + `concave points_worst` + fractal_dimension_worst

##                           Df   Deviance AIC
## - radius_se                1 8.9068e-08  44
## - smoothness_worst         1 9.2304e-08  44
## - texture_mean             1 9.2400e-08  44
## - `concave points_se`      1 9.4379e-08  44
## - area_worst               1 9.5293e-08  44
## - fractal_dimension_mean   1 9.5919e-08  44
## - area_mean                1 9.8743e-08  44
## - `concave points_worst`   1 9.9551e-08  44
## - texture_se               1 1.0078e-07  44
## - concavity_mean           1 1.0141e-07  44
## - concavity_se             1 1.0229e-07  44
## - compactness_mean         1 1.0388e-07  44
## - smoothness_se            1 1.0523e-07  44
## - compactness_worst        1 1.1500e-07  44
## - perimeter_mean           1 1.1866e-07  44
## - radius_mean              1 1.2674e-07  44
## - `concave points_mean`    1 1.5791e-07  44
## - perimeter_worst          1 1.5996e-07  44
## - symmetry_mean            1 1.7283e-07  44
## - texture_worst            1 1.7487e-07  44
## - fractal_dimension_se     1 2.0072e-07  44
## - fractal_dimension_worst  1 2.2715e-07  44
## <none>                       8.6642e-08  46



##
## Step:  AIC=44
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + `concave points_se` + fractal_dimension_se +
##     texture_worst + perimeter_worst + area_worst + smoothness_worst +
##     compactness_worst + `concave points_worst` + fractal_dimension_worst

##                           Df   Deviance AIC
## - `concave points_se`      1 9.3210e-08  42
## - smoothness_worst         1 9.6870e-08  42
## - area_worst               1 9.7070e-08  42
## - texture_mean             1 9.7270e-08  42
## - area_mean                1 9.8140e-08  42
## - fractal_dimension_mean   1 9.9510e-08  42
## - `concave points_worst`   1 1.0231e-07  42
## - concavity_se             1 1.0232e-07  42
## - compactness_mean         1 1.0402e-07  42
## - smoothness_se            1 1.0534e-07  42
## - concavity_mean           1 1.1368e-07  42
## - perimeter_mean           1 1.2133e-07  42
## - compactness_worst        1 1.2187e-07  42
## - texture_se               1 1.2555e-07  42
## - radius_mean              1 1.2974e-07  42
## - `concave points_mean`    1 1.5813e-07  42
## - symmetry_mean            1 1.7308e-07  42
## - perimeter_worst          1 1.7416e-07  42
## - fractal_dimension_se     1 2.0676e-07  42
## - fractal_dimension_worst  1 2.7645e-07  42
## - texture_worst            1 3.7774e-07  42
## <none>                       8.9070e-08  44

##
## Step:  AIC=42
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + fractal_dimension_se + texture_worst + perimeter_worst
+
##     area_worst + smoothness_worst + compactness_worst + `concave
points_worst` +
##     fractal_dimension_worst

##                           Df   Deviance AIC
## - smoothness_worst         1 9.7010e-08  40
## - fractal_dimension_mean   1 1.0038e-07  40
## - texture_mean             1 1.0072e-07  40
## - area_worst               1 1.0242e-07  40
## - compactness_mean         1 1.0414e-07  40
## - `concave points_worst`   1 1.0787e-07  40
## - area_mean                1 1.0841e-07  40
## - concavity_mean           1 1.1375e-07  40
## - texture_se               1 1.2613e-07  40
## - concavity_se             1 1.2635e-07  40
## - perimeter_mean          1 1.2761e-07  40
## - compactness_worst       1 1.2849e-07  40
## - radius_mean             1 1.3618e-07  40
## - `concave points_mean`   1 1.5873e-07  40
## - perimeter_worst         1 1.8312e-07  40
## - symmetry_mean           1 1.8322e-07  40
## - smoothness_se           1 2.3878e-07  40
## - fractal_dimension_se    1 2.7114e-07  40
## - fractal_dimension_worst  1 2.7667e-07  40
## - texture_worst           1 4.2134e-07  40
## <none>                      9.3210e-08  42

##
## Step:  AIC=40
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + fractal_dimension_se + texture_worst + perimeter_worst
+
##     area_worst + compactness_worst + `concave points_worst` +
##     fractal_dimension_worst

##                           Df Deviance   AIC
## - `concave points_worst`   1      0.0  38.0
## - area_worst               1      0.0  38.0
## - texture_mean             1      0.0  38.0
## - area_mean                1      0.0  38.0
## - compactness_mean         1      0.0  38.0
## - fractal_dimension_mean   1      0.0  38.0
## - texture_se               1      0.0  38.0
## - compactness_worst        1      0.0  38.0
## - concavity_se             1      0.0  38.0
## - perimeter_mean           1      0.0  38.0
## - concavity_mean           1      0.0  38.0
## - radius_mean              1      0.0  38.0
## - `concave points_mean`    1      0.0  38.0
## - symmetry_mean            1      0.0  38.0
## - perimeter_worst          1      0.0  38.0
## - fractal_dimension_worst  1      0.0  38.0
## - fractal_dimension_se     1      0.0  38.0
## - texture_worst            1      0.0  38.0
## <none>                            0.0  40.0
## - smoothness_se            1    576.7 614.7

##
## Step:  AIC=38
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + fractal_dimension_se + texture_worst + perimeter_worst
```

```
+
##     area_worst + compactness_worst + fractal_dimension_worst

##                           Df Deviance   AIC
## - area_worst               1     0.00 36.00
## - texture_mean             1     0.00 36.00
## - area_mean                1     0.00 36.00
## - compactness_worst        1     0.00 36.00
## - concavity_se             1     0.00 36.00
## - perimeter_mean           1     0.00 36.00
## - compactness_mean         1     0.00 36.00
## - fractal_dimension_mean   1     0.00 36.00
## - texture_se               1     0.00 36.00
## - radius_mean              1     0.00 36.00
## - concavity_mean           1     0.00 36.00
## - symmetry_mean            1     0.00 36.00
## - perimeter_worst          1     0.00 36.00
## - fractal_dimension_se     1     0.00 36.00
## - `concave points_mean`    1     0.00 36.00
## - texture_worst            1     0.00 36.00
## - fractal_dimension_worst  1     0.00 36.00
## <none>                          0.00 38.00
## - smoothness_se            1    15.66 51.66



##
## Step:  AIC=36
## diagnosis ~ radius_mean + texture_mean + perimeter_mean + area_mean +
##     compactness_mean + concavity_mean + `concave points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + fractal_dimension_se + texture_worst + perimeter_worst
+
##     compactness_worst + fractal_dimension_worst

##                           Df Deviance    AIC
## - texture_mean             1    0.000 34.000
## - area_mean                1    0.000 34.000
## - concavity_se             1    0.000 34.000
## - perimeter_mean           1    0.000 34.000
## - compactness_mean         1    0.000 34.000
## - fractal_dimension_mean   1    0.000 34.000
## - compactness_worst        1    0.000 34.000
## - radius_mean              1    0.000 34.000
## - texture_se               1    0.000 34.000
## - concavity_mean           1    0.000 34.000
## - symmetry_mean            1    0.000 34.000
## - `concave points_mean`    1    0.000 34.000
## - texture_worst            1    0.000 34.000
## - fractal_dimension_se     1    0.000 34.000
## - fractal_dimension_worst  1    0.000 34.000
## - perimeter_worst          1    0.000 34.000
## <none>                          0.000 36.000
## - smoothness_se            1   16.376 50.376

##
## Step:  AIC=34
## diagnosis ~ radius_mean + perimeter_mean + area_mean + compactness_mean +
##     concavity_mean + `concave points_mean` + symmetry_mean +
##     fractal_dimension_mean + texture_se + smoothness_se + concavity_se +
##     fractal_dimension_se + texture_worst + perimeter_worst +
##     compactness_worst + fractal_dimension_worst

##                           Df Deviance    AIC
## - area_mean                1    0.000 32.000
## - concavity_se             1    0.000 32.000
## - concavity_mean           1    0.000 32.000
## - texture_se               1    0.000 32.000
## - compactness_mean         1    0.000 32.000
## - fractal_dimension_mean   1    0.000 32.000
## - compactness_worst        1    0.000 32.000
## - perimeter_mean           1    0.000 32.000
## - radius_mean              1    0.000 32.000
## - symmetry_mean            1    0.000 32.000
## - `concave points_mean`    1    0.000 32.000
## - fractal_dimension_worst  1    0.000 32.000
## - texture_worst            1    0.000 32.000
## - perimeter_worst          1    0.000 32.000
## <none>                          0.000 34.000
## - fractal_dimension_se     1   11.508 43.508
## - smoothness_se            1   16.510 48.510

## Step:  AIC=32
## diagnosis ~ radius_mean + perimeter_mean + compactness_mean +
##     concavity_mean + `concave points_mean` + symmetry_mean +
##     fractal_dimension_mean + texture_se + smoothness_se + concavity_se +
##     fractal_dimension_se + texture_worst + perimeter_worst +
##     compactness_worst + fractal_dimension_worst

##                           Df Deviance    AIC
## - compactness_mean         1   0.0000 30.000
## - concavity_mean           1   0.0000 30.000
## - fractal_dimension_mean   1   0.0000 30.000
## - concavity_se             1   0.0000 30.000
## - texture_se               1   0.0000 30.000
## - compactness_worst        1   0.0000 30.000
## - radius_mean              1   0.0000 30.000
## - perimeter_mean           1   0.0000 30.000
## - symmetry_mean            1   0.0000 30.000
## - `concave points_mean`    1   0.0000 30.000
## - fractal_dimension_worst  1   0.0000 30.000
## - texture_worst            1   0.0001 30.000
## <none>                            0.0000 32.000
## - fractal_dimension_se     1  13.0179 43.018
## - smoothness_se            1  19.6823 49.682
## - perimeter_worst          1  21.4570 51.457

##
## Step:  AIC=30
## diagnosis ~ radius_mean + perimeter_mean + concavity_mean + `concave
points_mean` +
##     symmetry_mean + fractal_dimension_mean + texture_se + smoothness_se +
##     concavity_se + fractal_dimension_se + texture_worst + perimeter_worst
+
##     compactness_worst + fractal_dimension_worst



##                          Df Deviance    AIC
## - fractal_dimension_mean   1    0.000 28.000
## - concavity_se             1    0.000 28.000
## - concavity_mean           1    0.000 28.000
## - radius_mean              1    0.000 28.000
## - perimeter_mean           1    0.000 28.000
## - texture_se               1    0.000 28.000
## - symmetry_mean            1    0.000 28.000
## - `concave points_mean`    1    0.000 28.000
## - fractal_dimension_worst  1    0.000 28.000
## <none>                          0.000 30.000
## - compactness_worst        1   14.117 42.117
## - fractal_dimension_se     1   14.777 42.776
## - smoothness_se            1   19.950 47.950
## - perimeter_worst          1   22.404 50.404
## - texture_worst            1   26.821 54.821

## Warning: glm.fit: algorithm did not converge

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=28
## diagnosis ~ radius_mean + perimeter_mean + concavity_mean + `concave
points_mean` +
##     symmetry_mean + texture_se + smoothness_se + concavity_se +
##     fractal_dimension_se + texture_worst + perimeter_worst +
##     compactness_worst + fractal_dimension_worst

##                          Df Deviance    AIC
## - concavity_se             1    0.000 26.000
## - concavity_mean           1    0.000 26.000
## - radius_mean              1    0.000 26.000
## - perimeter_mean           1    0.000 26.000
## - texture_se               1    0.000 26.000
## - symmetry_mean            1    0.000 26.000
## - `concave points_mean`    1    0.000 26.000
## <none>                          0.000 28.000
## - fractal_dimension_se     1   14.813 40.813
## - compactness_worst        1   16.228 42.228
## - smoothness_se            1   22.103 48.103
## - fractal_dimension_worst  1   22.428 48.428
## - perimeter_worst          1   22.752 48.752
## - texture_worst            1   35.338 61.338
```

```
## Warning: glm.fit: algorithm did not converge

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## 
## Step:  AIC=26
## diagnosis ~ radius_mean + perimeter_mean + concavity_mean + `concave
points_mean` + 
##     symmetry_mean + texture_se + smoothness_se + fractal_dimension_se + 
##     texture_worst + perimeter_worst + compactness_worst + 
fractal_dimension_worst
```

```
##                           Df Deviance    AIC
## - perimeter_mean           1    0.000 24.000
## - radius_mean              1    0.000 24.000
## - texture_se               1    0.000 24.000
## - `concave points_mean`    1    0.000 24.000
## - symmetry_mean            1    0.000 24.000
## - concavity_mean           1    0.000 24.000
## <none>                          0.000 26.000
## - compactness_worst        1   16.608 40.608
## - fractal_dimension_worst  1   22.504 46.504
## - perimeter_worst          1   22.755 46.755
## - fractal_dimension_se     1   26.475 50.475
## - smoothness_se            1   28.536 52.536
## - texture_worst            1   36.802 60.802
```

```
## 
## Step:  AIC=24
## diagnosis ~ radius_mean + concavity_mean + `concave points_mean` + 
##     symmetry_mean + texture_se + smoothness_se + fractal_dimension_se + 
##     texture_worst + perimeter_worst + compactness_worst + 
fractal_dimension_worst
```

```
##                           Df Deviance    AIC
## - radius_mean              1    0.000 22.000
## - `concave points_mean`    1    0.000 22.000
## - texture_se               1    0.000 22.000
## <none>                          0.000 24.000
## - symmetry_mean            1    8.758 30.758
## - concavity_mean           1   10.055 32.055
## - compactness_worst        1   20.657 42.657
## - perimeter_worst          1   23.429 45.429
## - fractal_dimension_worst  1   26.673 48.673
## - fractal_dimension_se     1   40.354 62.354
## - smoothness_se            1   41.674 63.674
## - texture_worst            1   46.865 68.865

##
## Step:  AIC=22
## diagnosis ~ concavity_mean + `concave points_mean` + symmetry_mean +
##     texture_se + smoothness_se + fractal_dimension_se + texture_worst +
##     perimeter_worst + compactness_worst + fractal_dimension_worst

##                            Df Deviance    AIC
## - texture_se                1    0.000 20.000
## - `concave points_mean`     1    0.000 20.000
## <none>                           0.000 22.000
## - symmetry_mean             1   11.359 31.359
## - concavity_mean            1   12.771 32.771
## - compactness_worst         1   21.067 41.067
## - fractal_dimension_worst  1   31.257 51.257
## - smoothness_se            1   42.914 62.914
## - fractal_dimension_se     1   46.981 66.981
## - texture_worst            1   47.144 67.144
## - perimeter_worst          1   69.590 89.590

## Warning: glm.fit: algorithm did not converge

## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred

##
## Step:  AIC=20
## diagnosis ~ concavity_mean + `concave points_mean` + symmetry_mean +
##     smoothness_se + fractal_dimension_se + texture_worst + perimeter_worst
+
##     compactness_worst + fractal_dimension_worst

##                            Df Deviance     AIC
## <none>                           0.000  20.000
## - concavity_mean            1   18.073  36.073
## - `concave points_mean`     1   19.949  37.949
## - symmetry_mean             1   25.134  43.134
## - compactness_worst         1   27.324  45.324
## - fractal_dimension_worst  1   43.464  61.464
## - smoothness_se            1   45.694  63.694
## - fractal_dimension_se     1   54.866  72.866
## - texture_worst            1   56.170  74.170
## - perimeter_worst          1  101.702 119.702
```

```
summary(step_fit)
```

```
##
## Call:
## glm(formula = diagnosis ~ concavity_mean + `concave points_mean` +
##     symmetry_mean + smoothness_se + fractal_dimension_se + texture_worst +
##     perimeter_worst + compactness_worst + fractal_dimension_worst,
##     family = binomial(link = "logit"), data = train_data)
##
## Deviance Residuals:
##        Min          1Q      Median          3Q         Max
## -9.155e-04  -2.000e-08  -2.000e-08   2.000e-08   1.028e-03
##
## Coefficients:
##                           Estimate Std. Error z value Pr(>|z|)
## (Intercept)             -1.434e+04  3.496e+05  -0.041    0.967
## concavity_mean           4.805e+03  1.196e+05   0.040    0.968
## `concave points_mean`    8.822e+03  2.173e+05   0.041    0.968
## symmetry_mean            7.239e+03  1.808e+05   0.040    0.968
## smoothness_se            1.715e+05  4.174e+06   0.041    0.967
## fractal_dimension_se    -5.041e+05  1.225e+07  -0.041    0.967
## texture_worst            7.016e+01  1.710e+03   0.041    0.967
## perimeter_worst          5.920e+01  1.446e+03   0.041    0.967
## compactness_worst       -6.023e+03  1.469e+05  -0.041    0.967
## fractal_dimension_worst  7.318e+04  1.785e+06   0.041    0.967
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 5.6381e+02  on 426  degrees of freedom
## Residual deviance: 5.6950e-06  on 417  degrees of freedom
## AIC: 20
##
## Number of Fisher Scoring iterations: 25
```

```
confint(step_fit)
```

```
##                                 2.5 %      97.5 %
## (Intercept)             -2.004980e+05  -22898.638
## concavity_mean          -6.092841e+03   78980.638
## `concave points_mean`   -1.650539e+04  144613.722
## symmetry_mean           -1.076787e+04  121654.932
## smoothness_se           -2.475484e+05 2738198.040
## fractal_dimension_se    -7.894729e+06  765781.958
## texture_worst           -8.660910e+01    1047.087
## perimeter_worst         -5.280658e+01     917.796
## compactness_worst       -9.344200e+04   12900.424
## fractal_dimension_worst -1.312846e+05 1169411.619
```

```
#ANOVA on base model
anova(fit,test = 'Chisq')
```

```
## Model: binomial, link: logit
##
```

```
## Response: diagnosis
## 
## Terms added sequentially (first to last)
## 
## 
##                         Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                      426     563.81
## radius_mean              1   312.35       425     251.46 < 2.2e-16 ***
## texture_mean             1    22.22       424     229.24 2.431e-06 ***
## perimeter_mean           1    60.59       423     168.65 7.016e-15 ***
## area_mean                1     7.82       422     160.83 0.0051568 **
## smoothness_mean          1    34.03       421     126.79 5.416e-09 ***
## compactness_mean         1     0.02       420     126.77 0.8900612
## concavity_mean           1    11.89       419     114.88 0.0005637 ***
## `concave points_mean`    1     2.64       418     112.24 0.1041743
## symmetry_mean            1     3.55       417     108.69 0.0595695 .
## fractal_dimension_mean   1     0.48       416     108.21 0.4872629
## radius_se                1     4.78       415     103.42 0.0287116 *
## texture_se               1     9.47       414      93.95 0.0020869 **
## perimeter_se             1     0.05       413      93.90 0.8153014
## area_se                  1    12.15       412      81.75 0.0004913 ***
## smoothness_se            1     1.73       411      80.02 0.1883121
## compactness_se           1    20.73       410      59.29 5.295e-06 ***
## concavity_se             1     6.22       409      53.07 0.0126083 *
## `concave points_se`      1     1.12       408      51.94 0.2891473
## symmetry_se              1     1.00       407      50.94 0.3161479
## fractal_dimension_se     1     1.34       406      49.59 0.2461846
## radius_worst             1     0.00       405     648.79 1.0000000
## texture_worst            1   648.79       404       0.00 < 2.2e-16 ***
## perimeter_worst          1     0.00       403       0.00 0.9999778
## area_worst               1     0.00       402       0.00 0.9998569
## smoothness_worst         1     0.00       401       0.00 0.9998323
## compactness_worst        1     0.00       400       0.00 0.9998844
## concavity_worst          1     0.00       399       0.00 1.0000000
## `concave points_worst`   1     0.00       398       0.00 0.9999370
## symmetry_worst           1     0.00       397       0.00 1.0000000
## fractal_dimension_worst  1     0.00       396     504.61 1.0000000
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#ANOVA from reduced model after applying the Step AIC
anova(step_fit,test = 'Chisq')
```

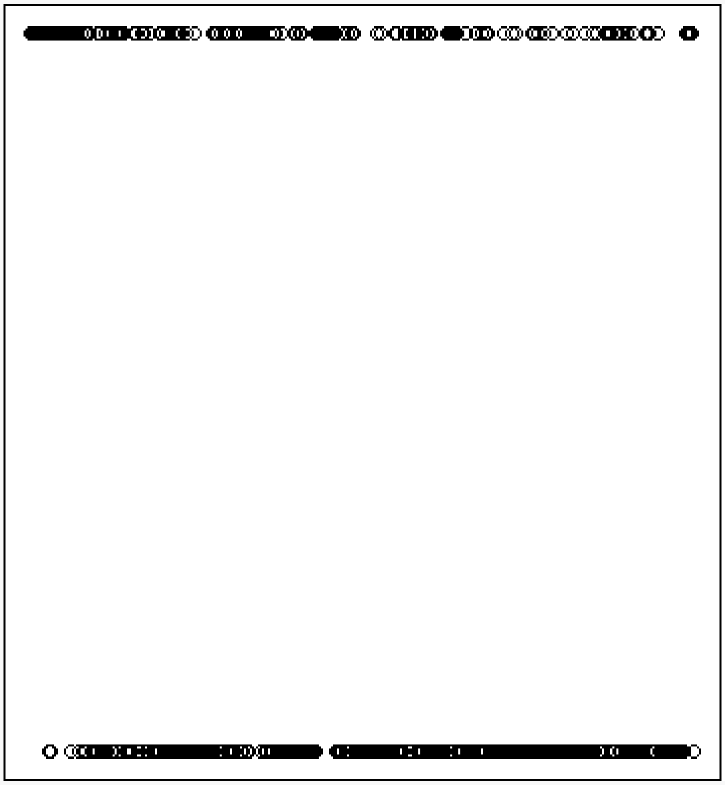
```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## Warning: glm.fit: fitted probabilities numerically 0 or 1 occurred
```

```
## Analysis of Deviance Table
## 
## Model: binomial, link: logit
```

```
##
## Response: diagnosis
##
## Terms added sequentially (first to last)
##
##
##                          Df Deviance Resid. Df Resid. Dev  Pr(>Chi)
## NULL                                      426     563.81
## concavity_mean           1  290.218       425     273.60 < 2.2e-16 ***
## `concave points_mean`    1   76.300       424     197.30 < 2.2e-16 ***
## symmetry_mean            1    4.970       423     192.32   0.02578 *
## smoothness_se            1    6.224       422     186.10   0.01260 *
## fractal_dimension_se     1   33.111       421     152.99 8.706e-09 ***
## texture_worst            1   46.144       420     106.85 1.099e-11 ***
## perimeter_worst          1   59.618       419      47.23 1.152e-14 ***
## compactness_worst        1    3.765       418      43.46   0.05234 .
## fractal_dimension_worst  1   43.464       417       0.00 4.319e-11 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
#plot the fitted model
```



```
plot.new()

plot(fit$fitted.values)
pred_link <- predict(fit,newdata = test_data,type = 'link')
```

```r
#check for multicollinearity
library(car)
```

```
## Loading required package: carData
```

```
## 
## Attaching package: 'car'
```

```
## The following object is masked from 'package:modeltools':
## 
##     Predict
```

```r
vif(fit)
```

```
##             radius_mean            texture_mean          perimeter_mean 
##             4231.240532               12.057374             4114.484019 
##               area_mean         smoothness_mean        compactness_mean 
##              357.762613                9.570587               55.757803 
##          concavity_mean   `concave points_mean`           symmetry_mean 
##               79.562151               59.693761                4.277740 
##  fractal_dimension_mean               radius_se              texture_se 
##               16.406891              100.057360                3.980190 
##            perimeter_se                 area_se           smoothness_se 
##               92.303083               47.935390                4.114137 
##          compactness_se            concavity_se     `concave points_se` 
##               17.218922               16.063111               13.374578 
##             symmetry_se    fractal_dimension_se            radius_worst 
##                5.415910               11.916743              960.040406 
##           texture_worst         perimeter_worst              area_worst 
##               18.054760              454.037215              386.858470 
##        smoothness_worst       compactness_worst         concavity_worst 
##               12.427398               37.442475               34.364483 
##  `concave points_worst`          symmetry_worst fractal_dimension_worst 
##               43.557508                9.363305               17.264083
```

```r
vif(step_fit)
```

```
##          concavity_mean   `concave points_mean`           symmetry_mean 
##               244.05337                99.94645               317.05513 
##           smoothness_se    fractal_dimension_se           texture_worst 
##              4608.37740              6335.09066              1093.86196 
##         perimeter_worst       compactness_worst fractal_dimension_worst 
##              1517.71228              5118.72975              6430.41696
```

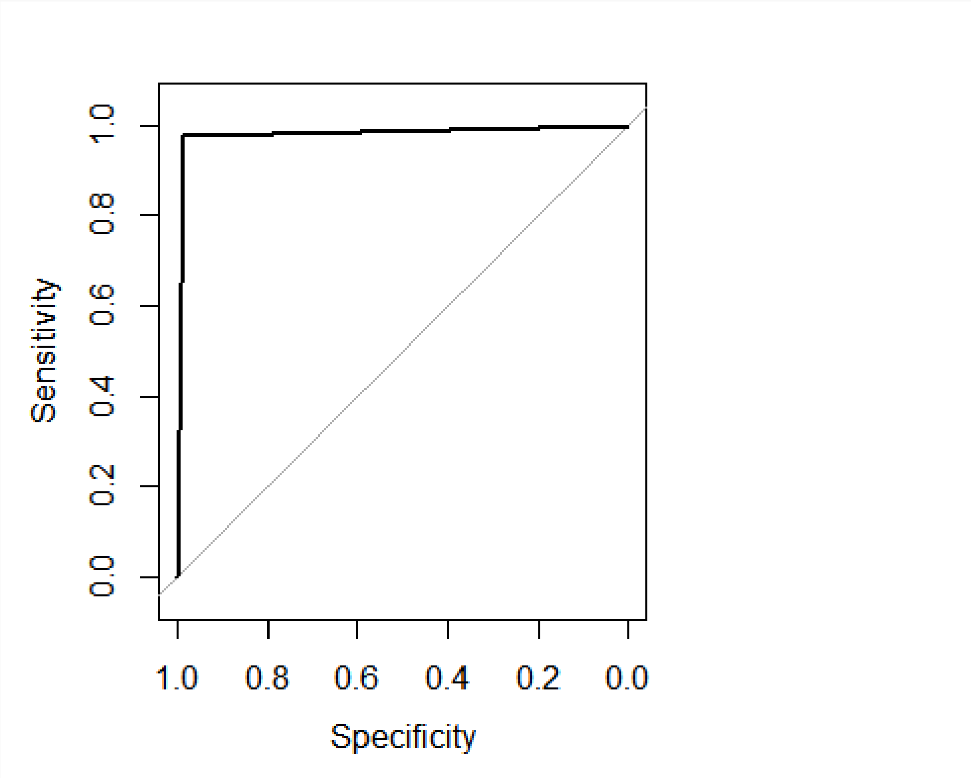
```r
pred <- predict(fit,newdata =test_data ,type ='response')
#check the AUC curve
library(pROC)
g <- roc(diagnosis ~ pred, data = test_data)
g
```

```
## 
## Call:
```

```
## roc.formula(formula = diagnosis ~ pred, data = test_data)
##
## Data: pred in 268 controls (diagnosis B) < 159 cases (diagnosis M).
## Area under the curve: 0.9818
```

```
plot.new()
```

```
plot(g)
```



```
library(caret)
#with default prob cut 0.50
test_data$pred_diagnosis <- ifelse(pred<0.5,'yes','no')
```

```
table(test_data$pred_diagnosis,test_data$diagnosis)
```

```
##
##          B   M
##   no     3 155
##   yes 265   4
```

```
#training split of diagnosis classes
round(table(train_data$diagnosis)/nrow(train_data),2)*100
```

```
##
##  B  M
## 63 37
```

```
# test split of diagnosis
round(table(test_data$diagnosis)/nrow(test_data),2)*100
```

```
##
##   B  M
## 63 37
```

```r
#predicted split of diagnosis
round(table(test_data$pred_diagnosis)/nrow(test_data),2)*100
```

```
##
##   no yes
##   37  63
```

```r
#create confusion matrix
#confusionMatrix(test_data$diagnosis,test_data$pred_diagnosis)
#how do we create a cross validation scheme
control <- trainControl(method = 'repeatedcv',
                        number = 10,
                        repeats = 3)
seed <-7
metric <- 'Accuracy'
set.seed(seed)
fit_default <- train(diagnosis~.,
                     data = train_data,
                     method = 'glm',
                     metric =metric ,
                     trControl = control)

print(fit_default)
```

```
## Generalized Linear Model
##
## 427 samples
##  30 predictor
##   2 classes: 'B', 'M'
##
## No pre-processing
## Resampling: Cross-Validated (10 fold, repeated 3 times)
## Summary of sample sizes: 384, 384, 385, 384, 385, 384, ...
## Resampling results:
##
##   Accuracy   Kappa
##   0.9516242  0.8968547
```

```r
library(caret)
varImp(step_fit)
```

```
##                             Overall
## concavity_mean           0.04016248
## `concave points_mean`    0.04060020
## symmetry_mean            0.04004251
## smoothness_se            0.04107363
## fractal_dimension_se     0.04113828
## texture_worst            0.04104256
## perimeter_worst          0.04095488
## compactness_worst        0.04099049
## fractal_dimension_worst 0.04099415
```

```
varImp(fit_default)
```

```
## glm variable importance
##
##   only 20 most important variables shown (out of 30)
##
##                                 Overall
## texture_worst                    100.00
## `\\`concave points_mean\\``       98.74
## area_worst                        91.99
## texture_se                        85.62
## area_mean                         79.84
## perimeter_worst                   72.42
## radius_worst                      71.29
## symmetry_se                       70.27
## compactness_mean                  64.41
## smoothness_se                     57.38
## concavity_worst                   53.05
## perimeter_mean                    43.43
## texture_mean                      42.20
## `\\`concave points_worst\\``      32.62
## smoothness_mean                   30.88
## compactness_se                    29.91
## concavity_se                      25.74
## `\\`concave points_se\\``         24.75
## compactness_worst                 21.91
## fractal_dimension_worst           21.67
```

```
#4. MARS (earth package)
#The earth package implements variable importance based on Generalized cross validation (GCV),
#number of subset models the variable occurs (nsubsets) and residual sum of squares (RSS).
library(earth)
```

```
## Loading required package: plotmo
```

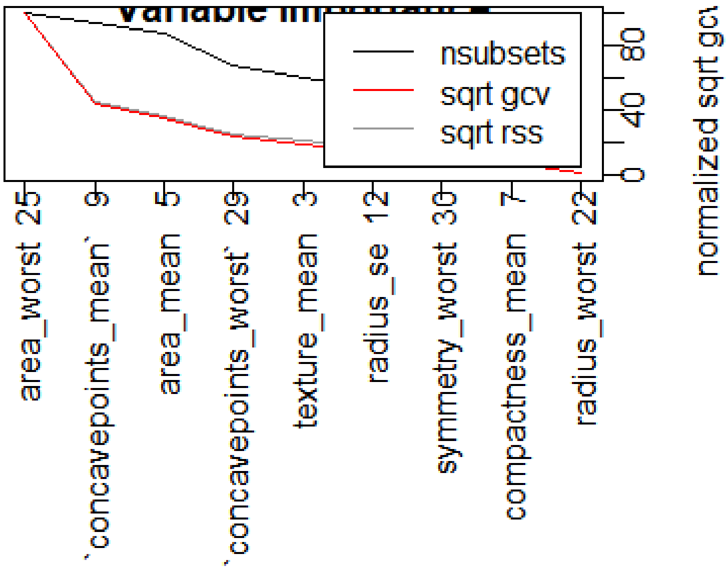
```
## Loading required package: plotrix
```

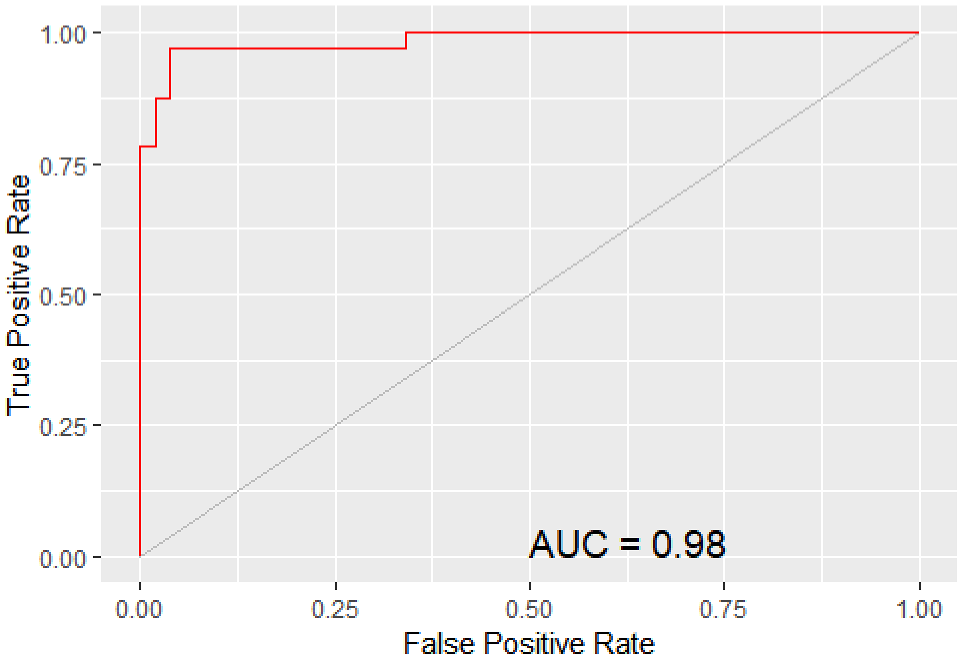
```
## Loading required package: TeachingDemos
```

```
marsModel<-earth(diagnosis~ ., data=data) # build model
ev <- evimp (marsModel) # estimate variable importance
ev
```

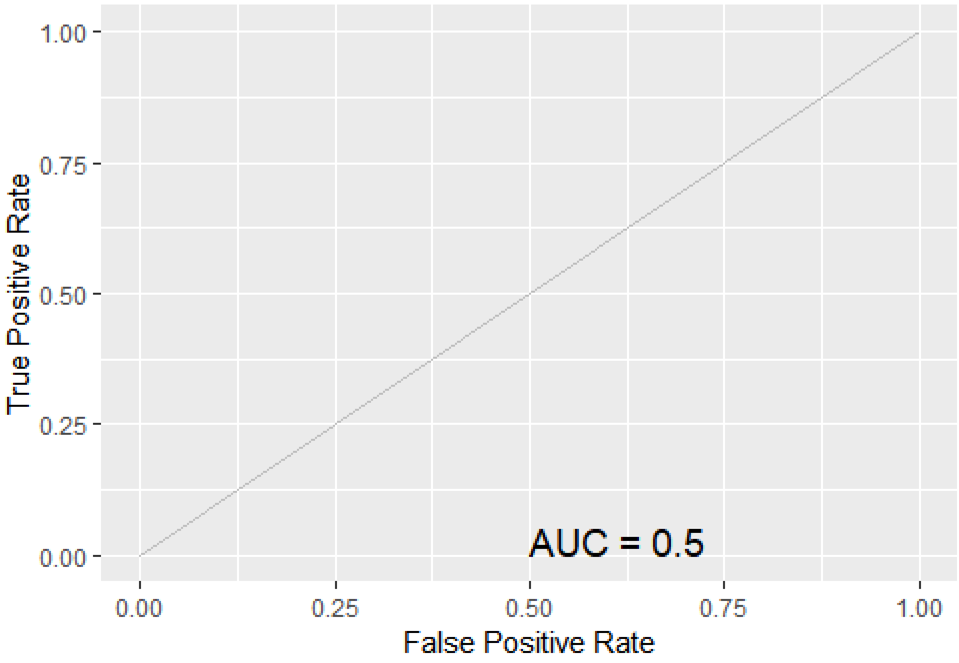
```
##                       nsubsets   gcv    rss
## area_worst                  15 100.0  100.0
## `concavepoints_mean`        14   43.1    44.5
## area_mean                   13   34.5    36.2
## `concavepoints_worst`       10   22.9    24.9
## texture_mean                 9   18.2    20.5
## radius_se                    8   13.3    16.2
## symmetry_worst               7    9.6    13.0
## compactness_mean             6    7.6    11.1
## radius_worst                 2    1.5     5.1
```

```
plot.new()

plot (ev)
```



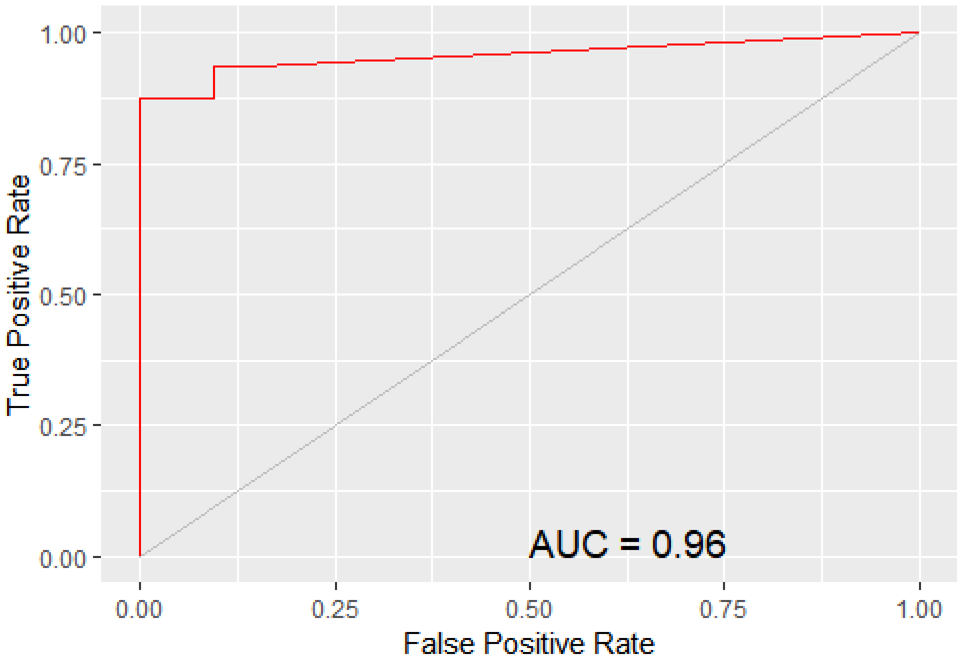


ROC Curve Random Forest CancerData.csv [validate] diagnosis

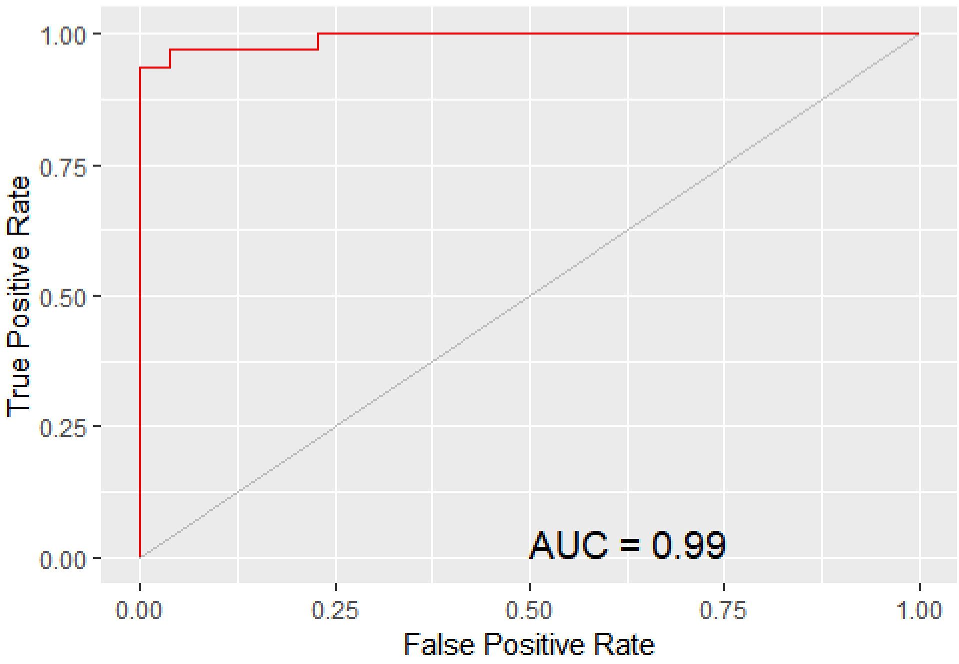


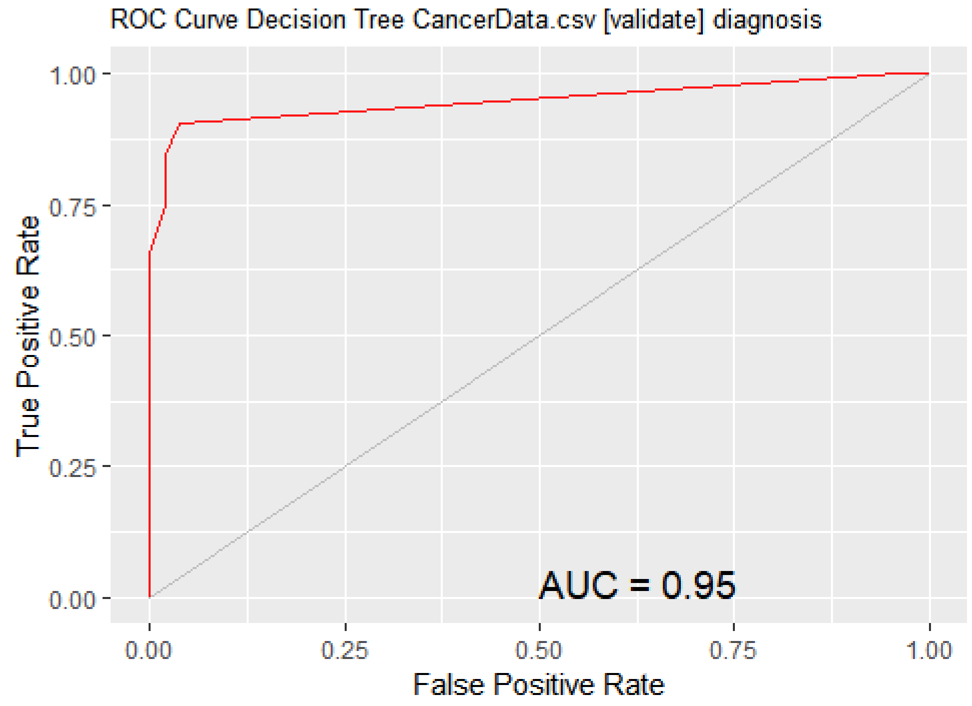
ROC Curve Neural Net CancerData.csv [validate] diagnosis

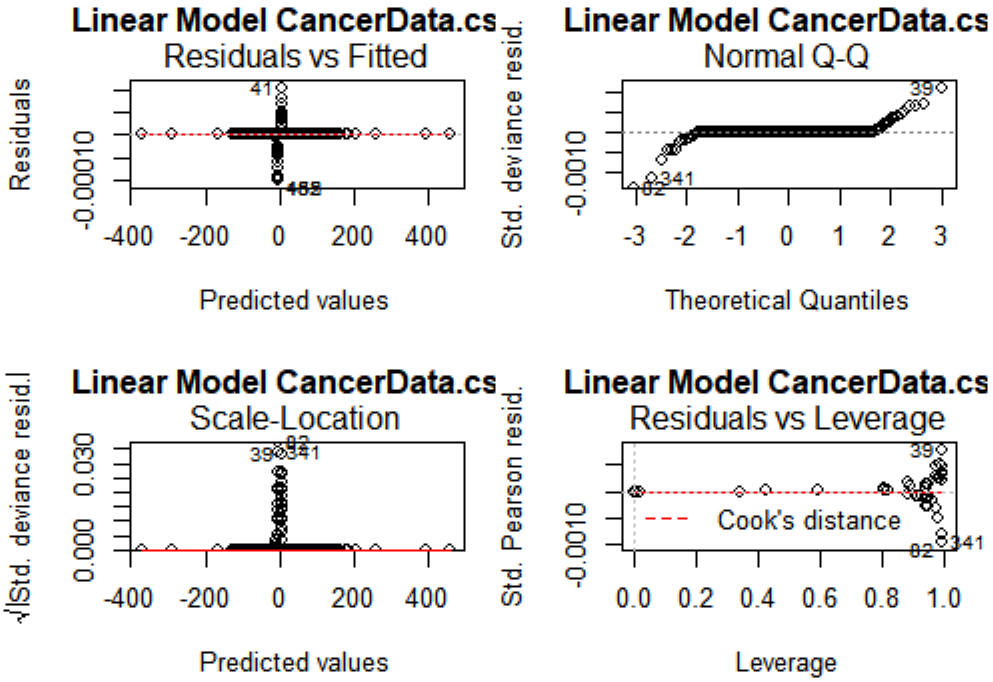
ROC Curve Linear CancerData.csv [validate] diagnosis



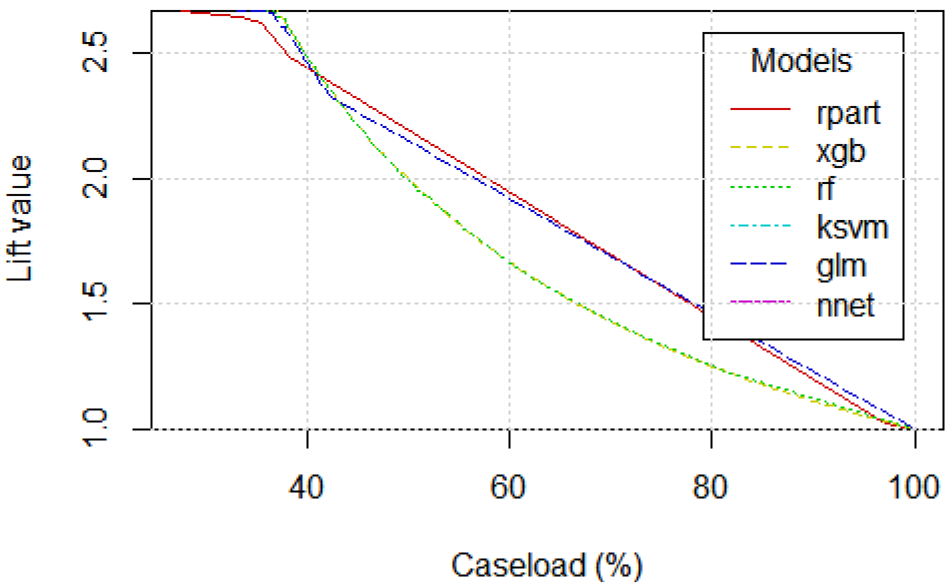
ROC Curve Extreme Boost CancerData.csv [validate] diagnosis



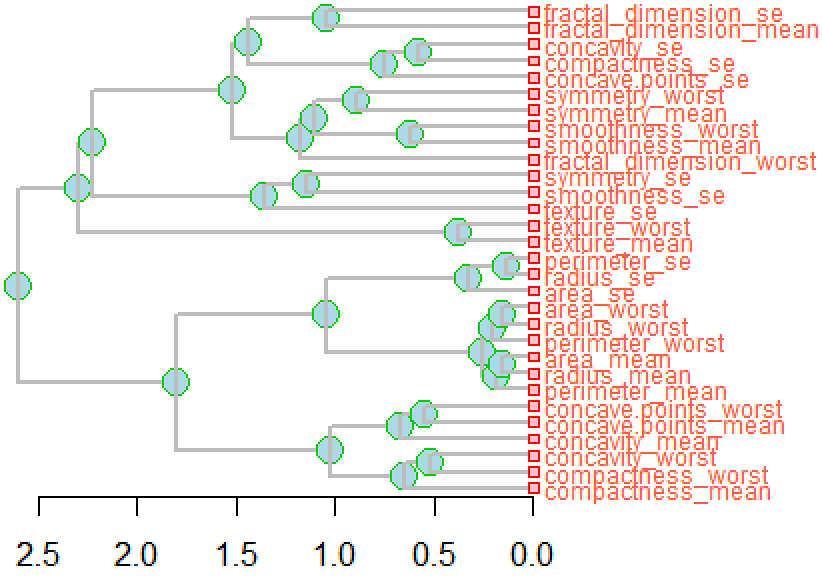

ROC Curve Decision Tree CancerData.csv [validate] diagnosis
True Positive Rate
1.00
0.75
0.50
0.25
0.00
AUC = 0.95
0.00
0.25
0.50
0.75
1.00
False Positive Rate

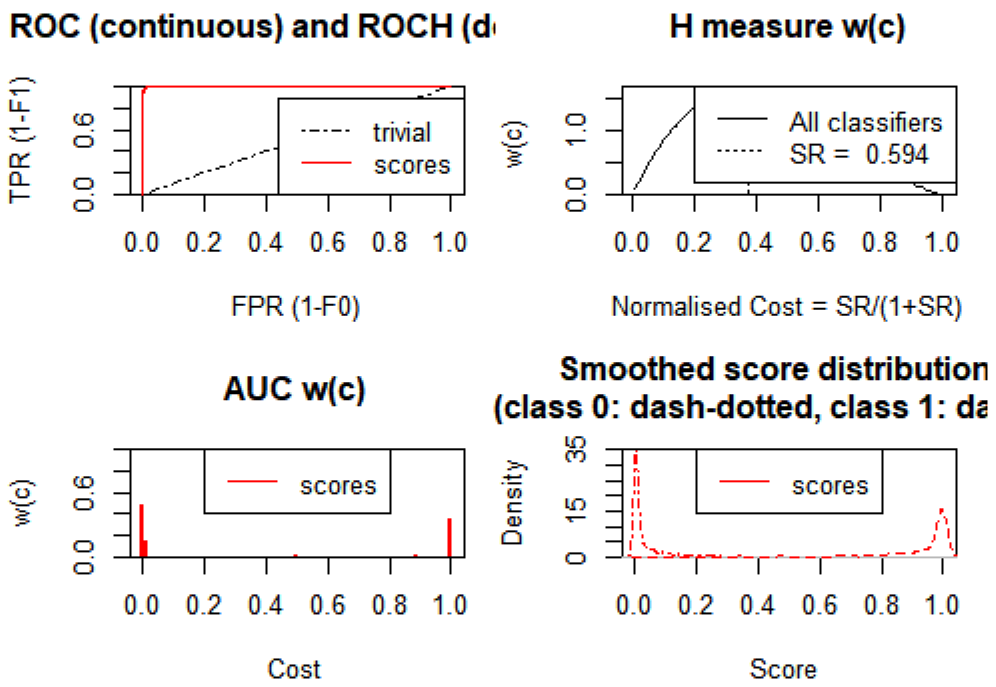

Linear Model CancerData.cs
Residuals vs Fitted
Residuals
-0.00010
41
455
-400
-200
0
200
400
Predicted values
Linear Model CancerData.cs
Normal Q-Q
Std. deviance resid.
-0.0010
39
82
341
-3
-2
-1
0
1
2
3
Theoretical Quantiles
Linear Model CancerData.cs
Scale-Location
√|Std. deviance resid.|
0.000
0.030
39
82
341
-400
-200
0
200
400
Predicted values
Linear Model CancerData.cs
Residuals vs Leverage
Std. Pearson resid.
-0.0010
39
Cook's distance
82
341
0.0
0.2
0.4
0.6
0.8
1.0
Leverage

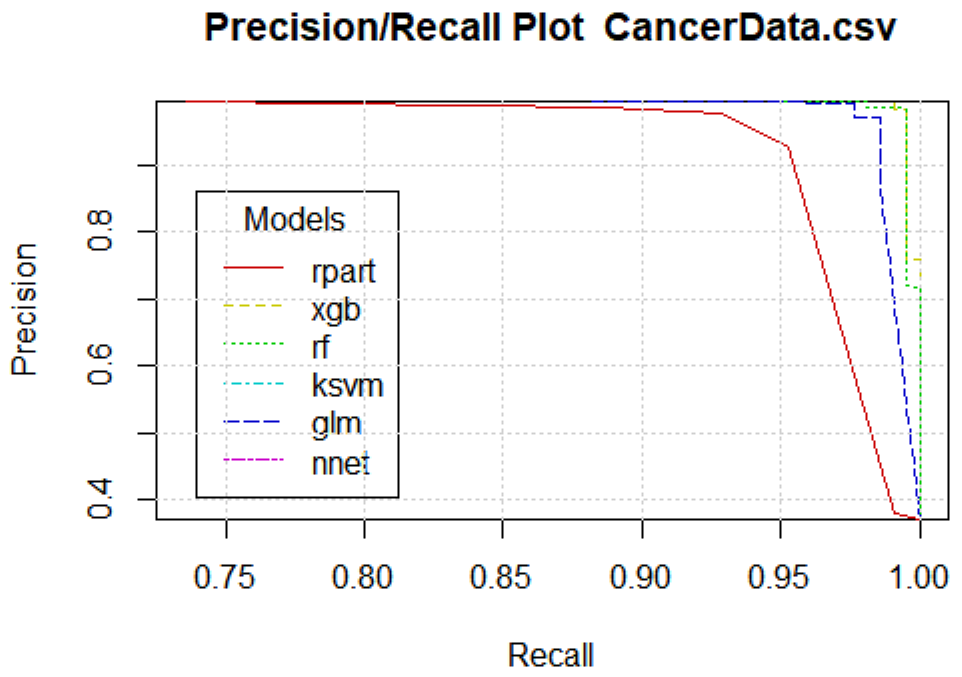
Lift Chart CancerData.csv

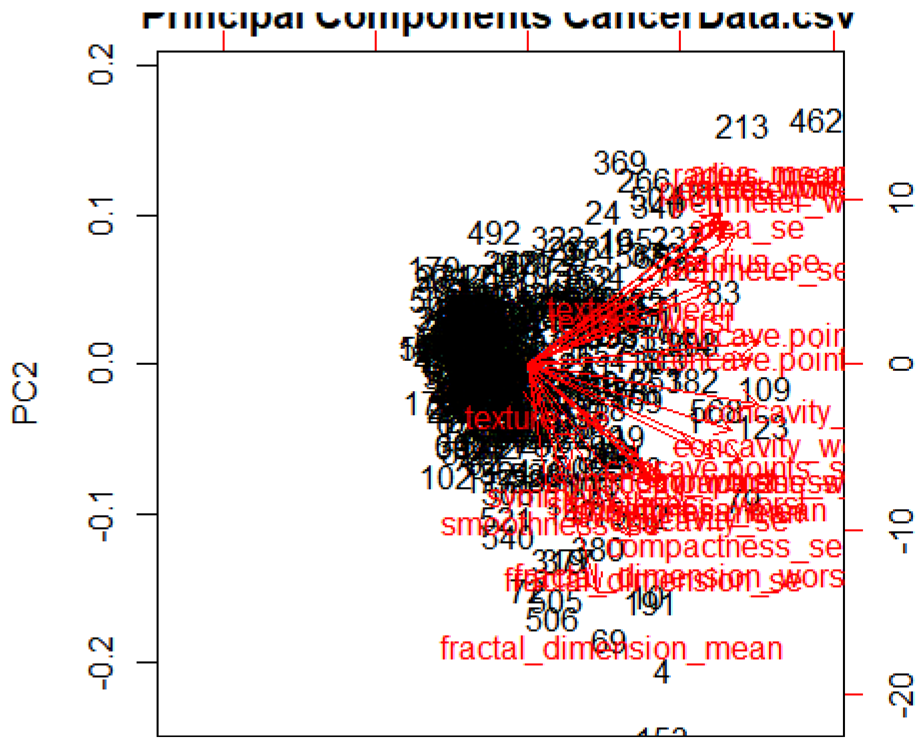


Variable Correlation Clusters
CancerData.csv using Pearson

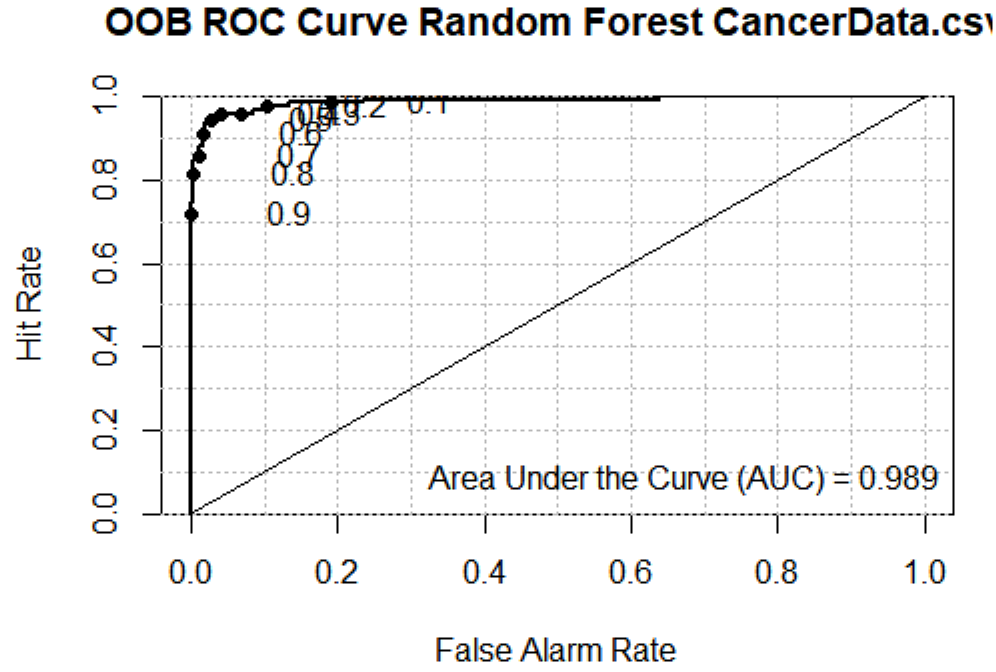



ROC (continuous) and ROCH (d
TPR (1-F1)
0.0
0.6
0.0
0.2
0.4
0.6
0.8
1.0
FPR (1-F0)
trivial
scores
H measure w(c)
w(c)
0.0
1.0
0.0
0.2
0.4
0.6
0.8
1.0
Normalised Cost = SR/(1+SR)
All classifiers
SR = 0.594
AUC w(c)
w(c)
0.0
0.6
0.0
0.2
0.4
0.6
0.8
1.0
Cost
scores
Smoothed score distribution
(class 0: dash-dotted, class 1: da
Density
0
15
35
0.0
0.2
0.4
0.6
0.8
1.0
Score
scores

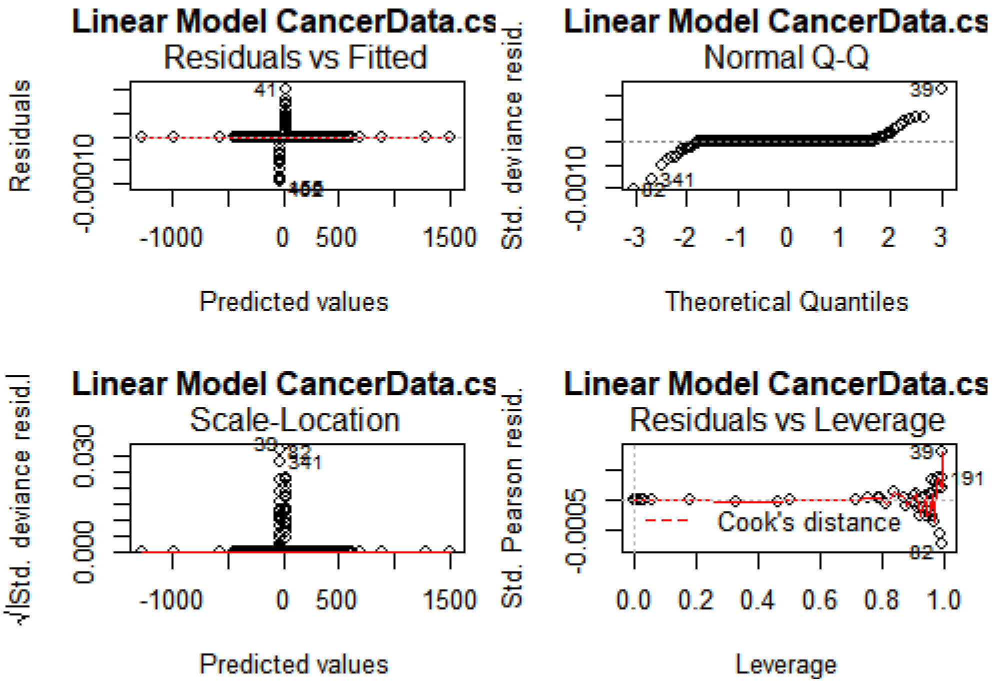

Precision/Recall Plot CancerData.csv
Precision
0.4
0.6
0.8
0.75
0.80
0.85
0.90
0.95
1.00
Recall
Models
rpart
xgb
rf
ksvm
glm
nnet

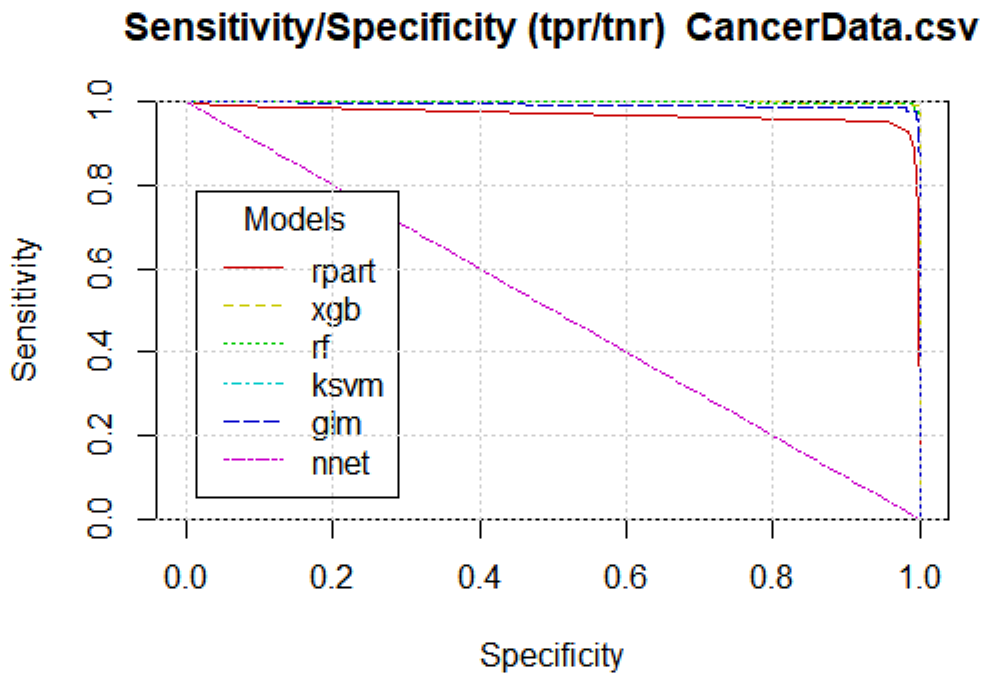


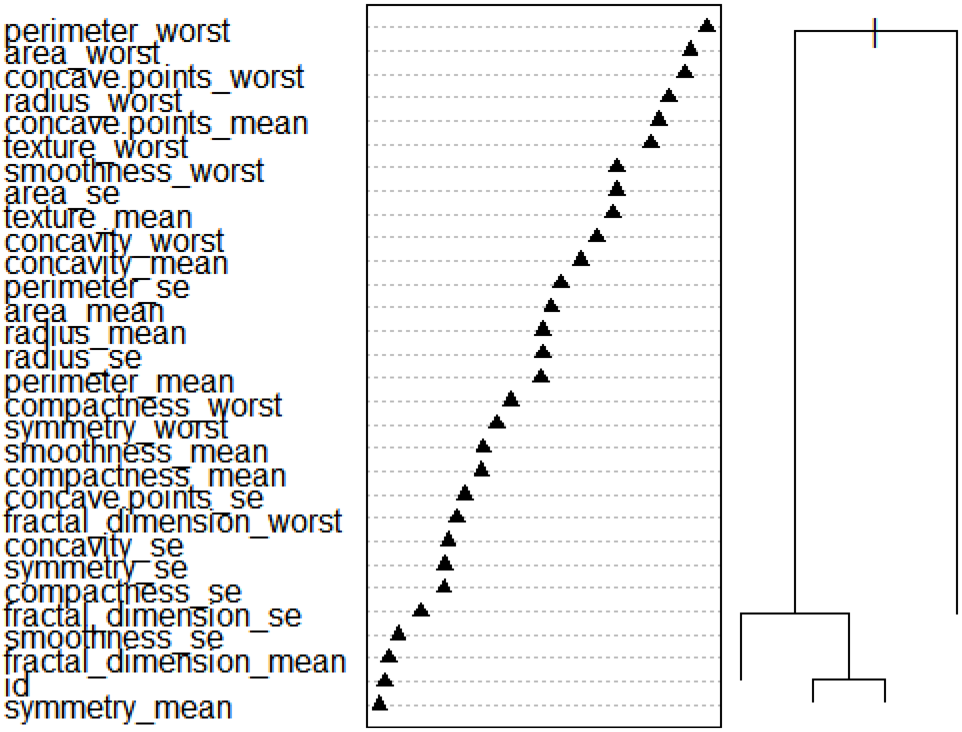
Principal Components CancerData.csv

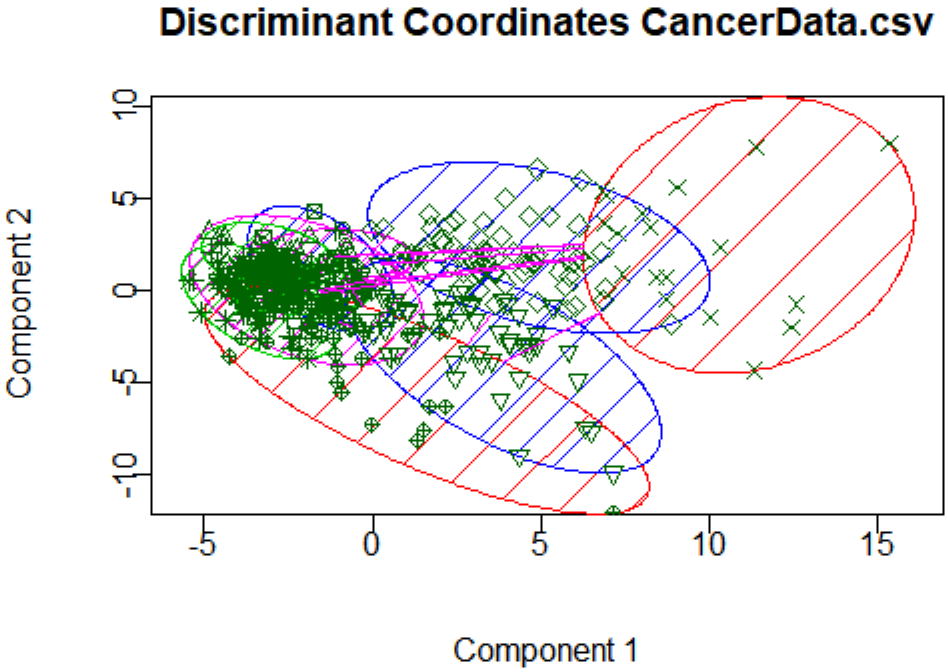


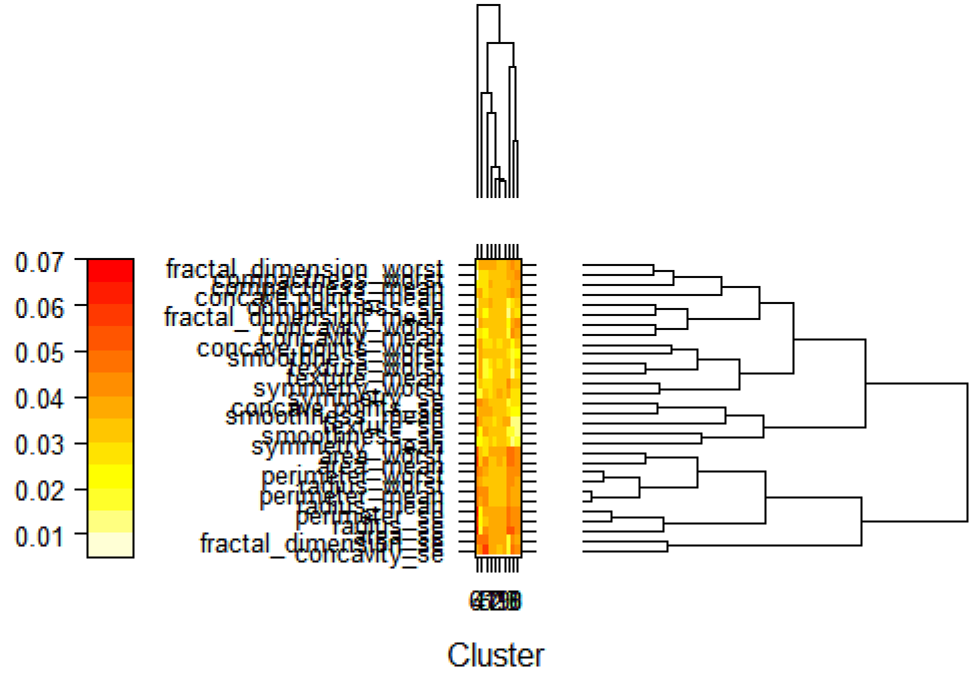
OOB ROC Curve Random Forest CancerData.csv

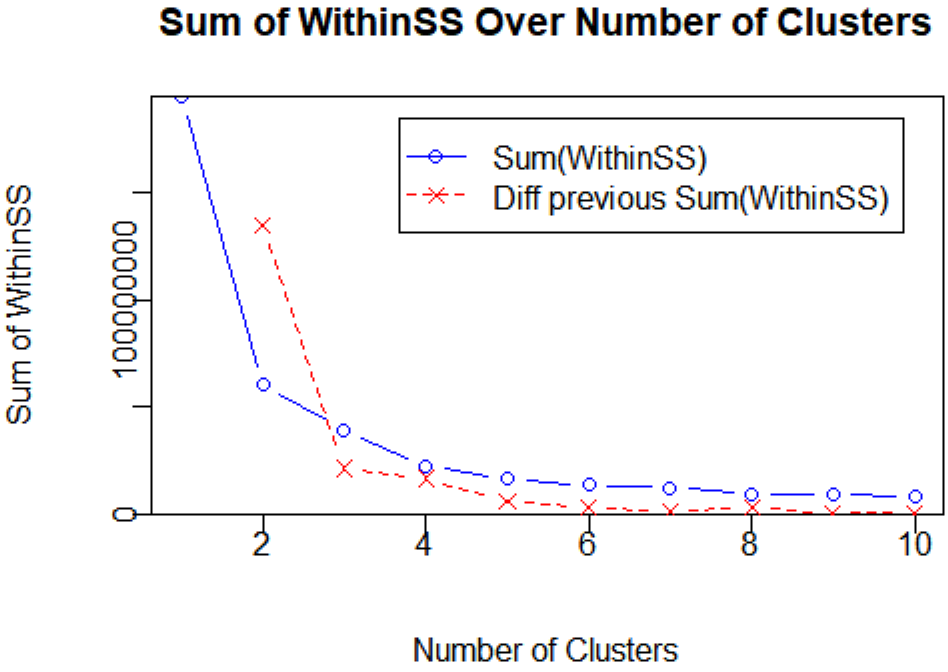

Linear Model CancerData.cs
Residuals vs Fitted
Residuals
-0.00010
41
455
-1000
0
500
1500
Predicted values
Linear Model CancerData.cs
Normal Q-Q
Std. deviance resid.
-0.0010
39
341
82
-3
-2
-1
0
1
2
3
Theoretical Quantiles
Linear Model CancerData.cs
Scale-Location
√|Std. deviance resid.|
0.000
0.030
39
82
341
-1000
0
500
1500
Predicted values
Linear Model CancerData.cs
Residuals vs Leverage
Std. Pearson resid.
-0.0005
39
191
82
Cook's distance
0.0
0.2
0.4
0.6
0.8
1.0
Leverage

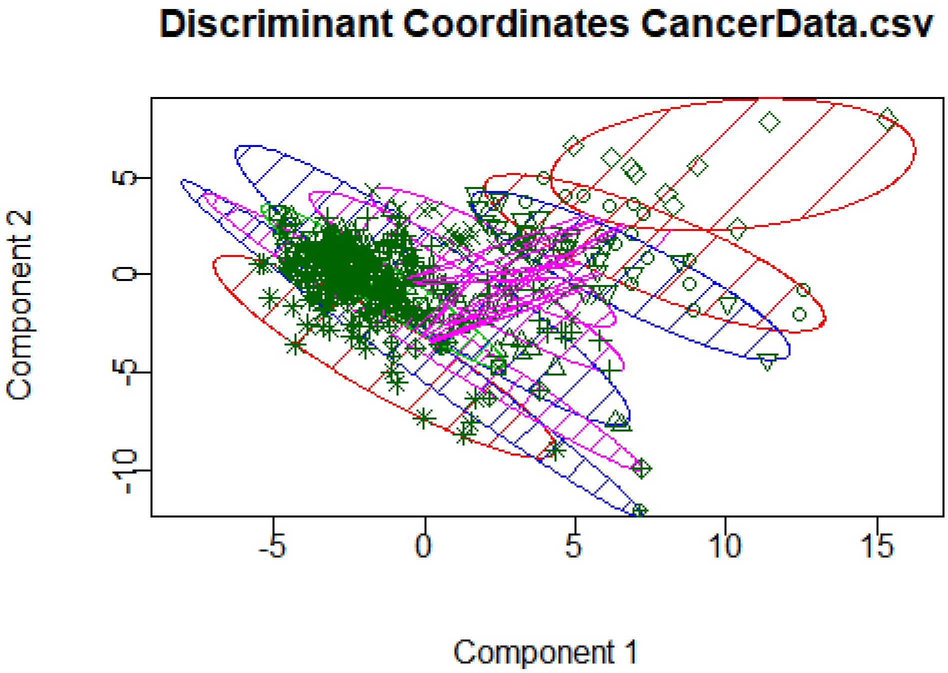

Sensitivity/Specificity (tpr/tnr) CancerData.csv
Sensitivity
0.0
0.2
0.4
0.6
0.8
1.0
Models
rpart
xgb
rf
ksvm
glm
nnet
0.0
0.2
0.4
0.6
0.8
1.0
Specificity

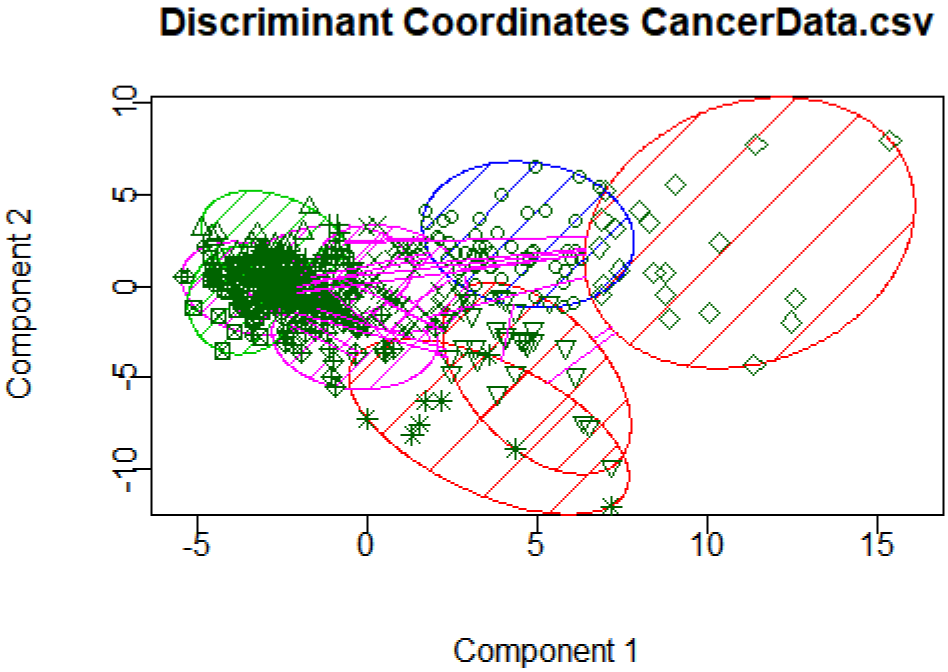

perimeter_worst
area_worst
concave.points_worst
radius_worst
concave.points_mean
texture_worst
smoothness_worst
area_se
texture_mean
concavity_worst
concavity_mean
perimeter_se
area_mean
radius_mean
radius_se
perimeter_mean
compactness_worst
symmetry_worst
smoothness_mean
compactness_mean
concave.points_se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

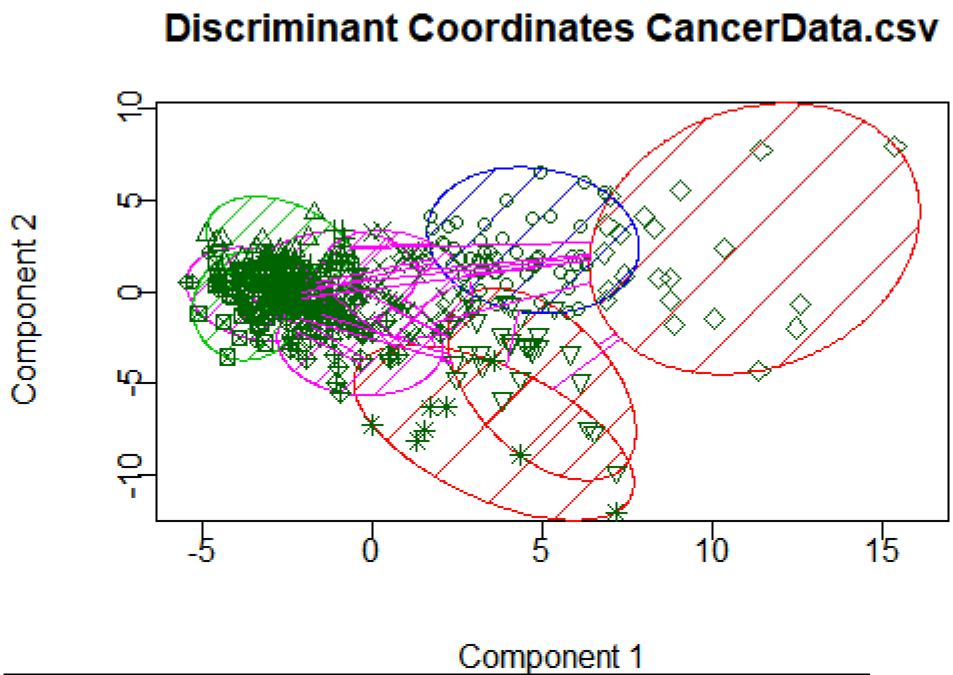

Discriminant Coordinates CancerData.csv
Component 2
10
5
0
-5
-10
Component 1
-5
0
5
10
15

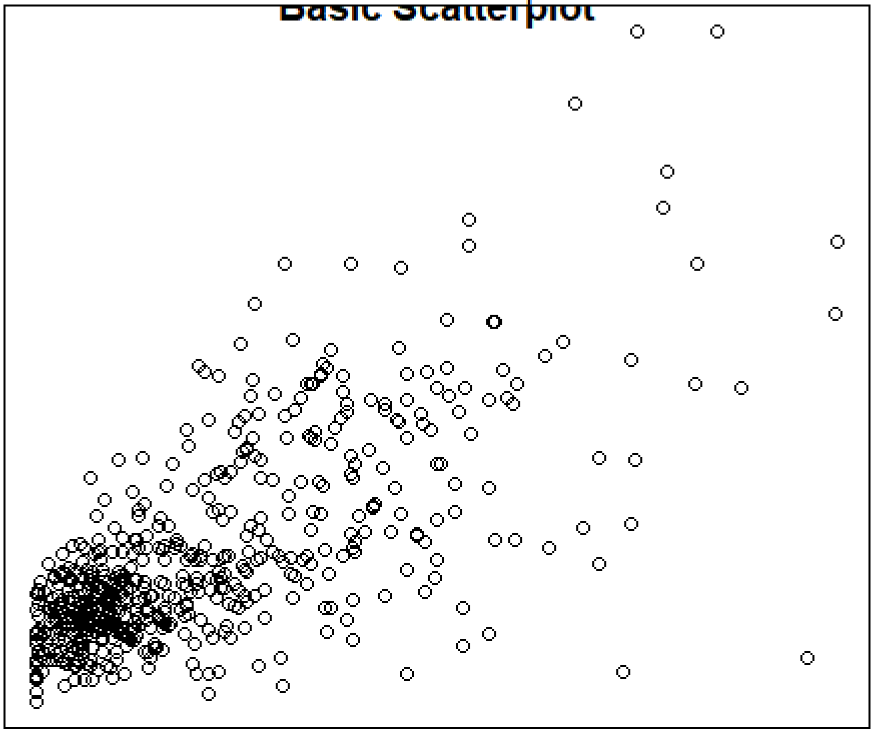

0.07
0.06
0.05
0.04
0.03
0.02
0.01
fractal_dimension_worst
compactness_worst
compactness_mean
concave points_mean
fractal_dimension_mean
concavity_worst
concavity_mean
concave points_worst
smoothness_worst
texture_worst
texture_mean
symmetry_worst
symmetry_se
concave points_se
smoothness_mean
texture_se
smoothness_se
symmetry_mean
area_worst
area_mean
perimeter_worst
radius_worst
perimeter_mean
radius_mean
perimeter_se
radius_se
area_se
fractal_dimension_se
concavity_se
Cluster


Sum of WithinSS Over Number of Clusters
Sum(WithinSS)
Diff previous Sum(WithinSS)
Sum of WithinSS
0
100000000
2
4
6
8
10
Number of Clusters

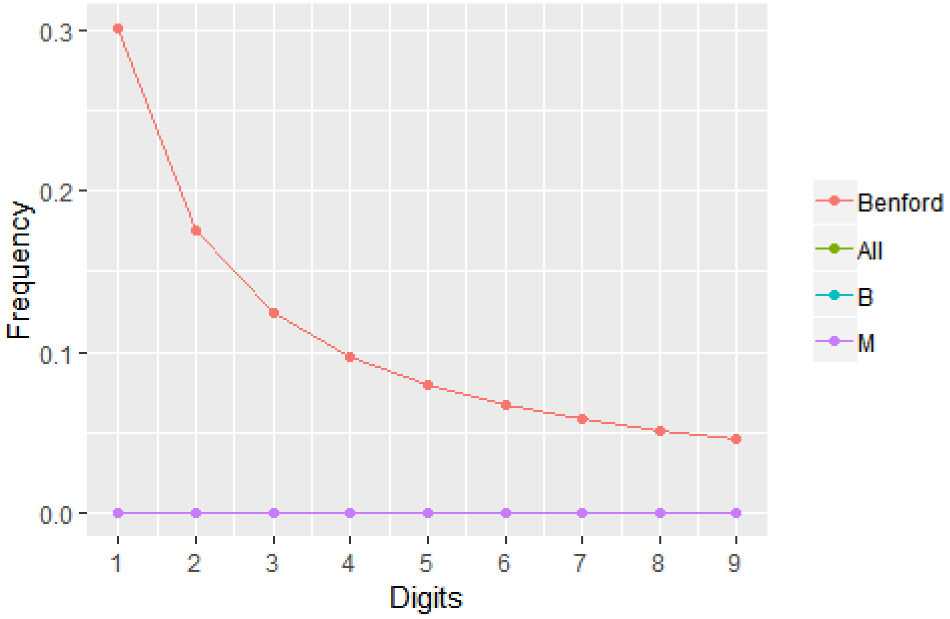

Discriminant Coordinates CancerData.csv
Component 2
5
0
-5
-10
-5
0
5
10
15
Component 1

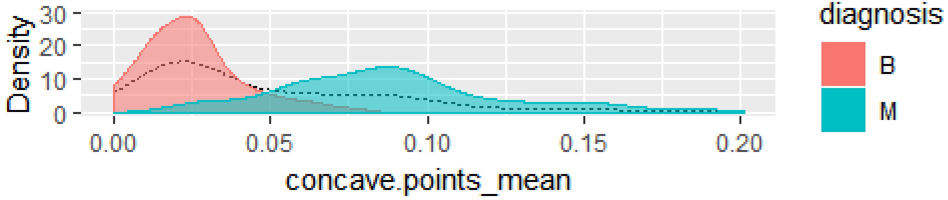

Discriminant Coordinates CancerData.csv
Component 2
10
5
0
-5
-10
-5
0
5
10
15
Component 1



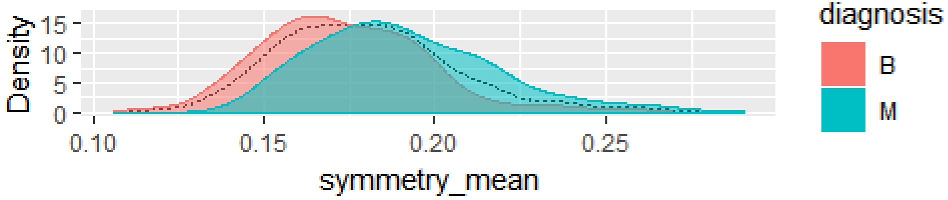


Other plots through Rattle

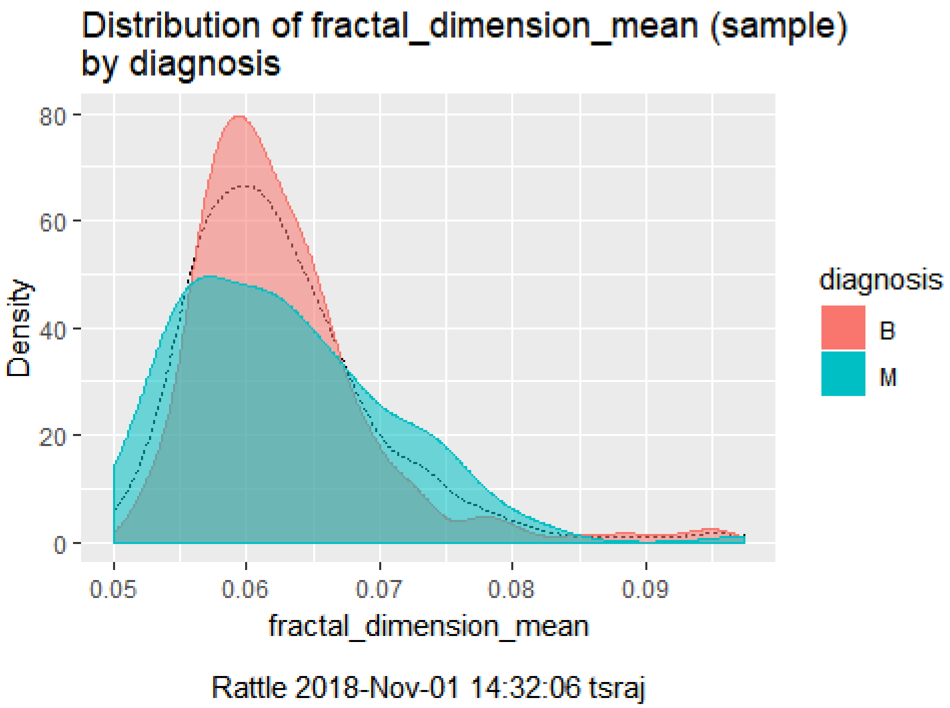

Digital Analysis of First Digit
of concave.points_mean by diagnosis


Distribution of concave.points_mean (sample)
by diagnosis

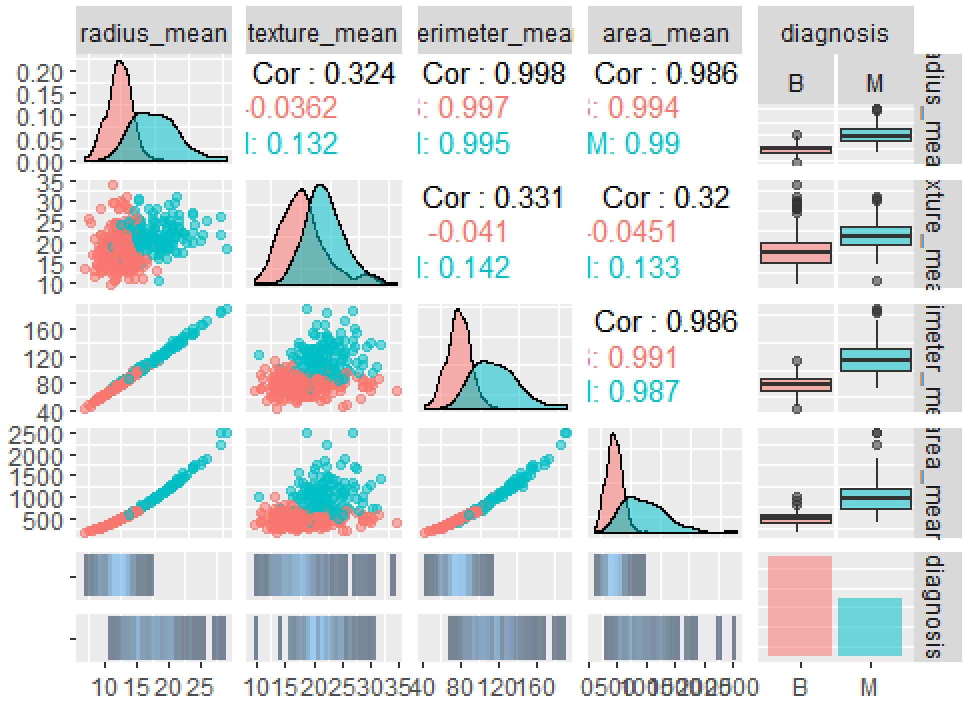
Rattle 2018-Nov-01 14:23:33 tsraj

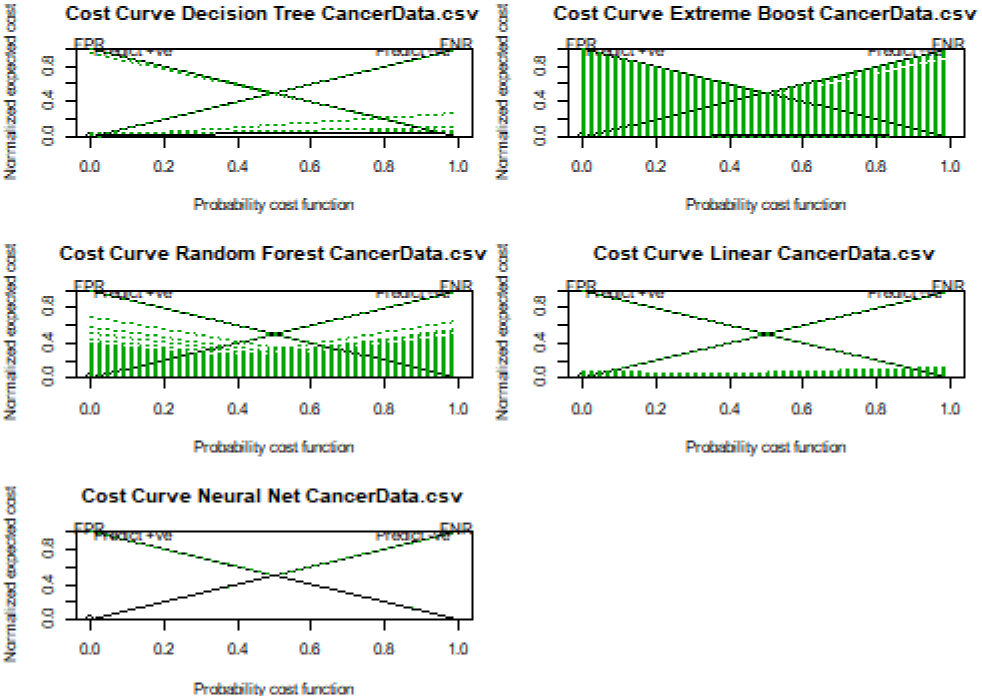

Distribution of symmetry_mean (sample)
by diagnosis

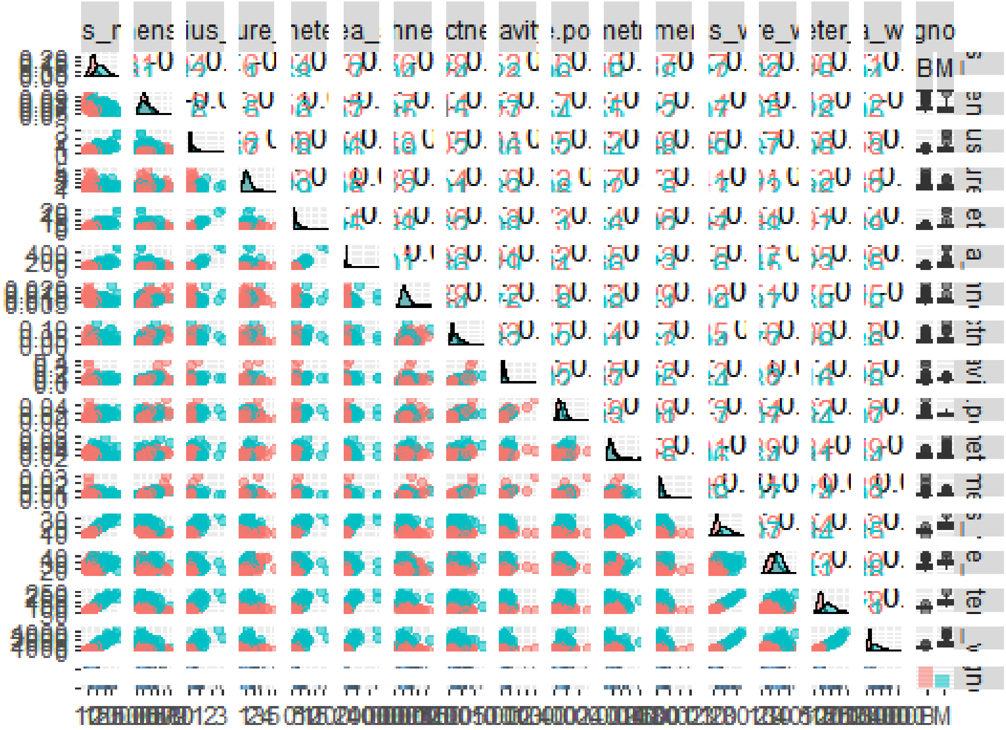
Rattle 2018-Nov-01 14:23:35 tsraj

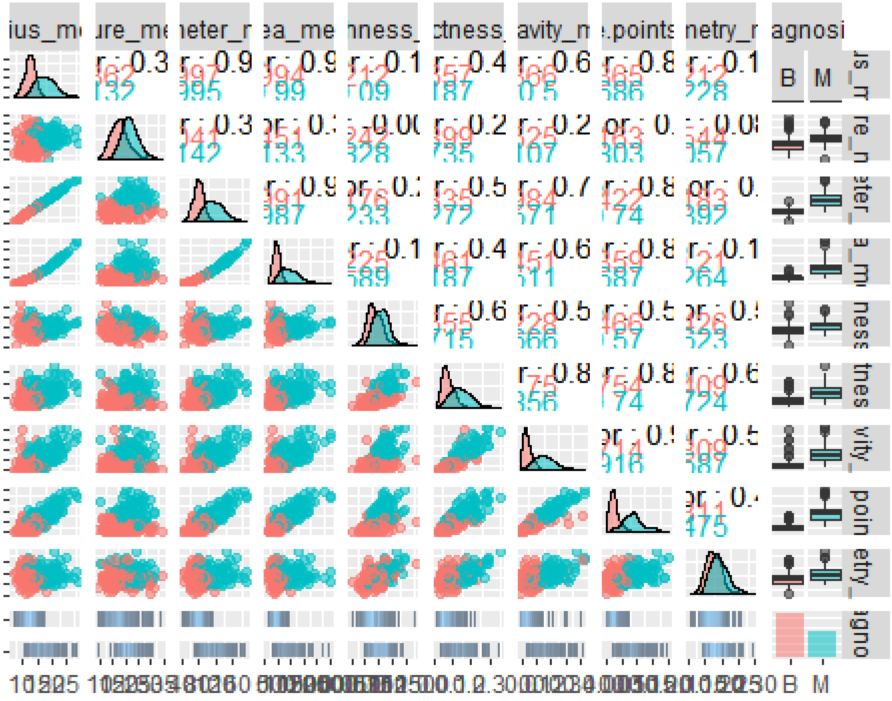

Distribution of fractal_dimension_mean (sample) by diagnosis

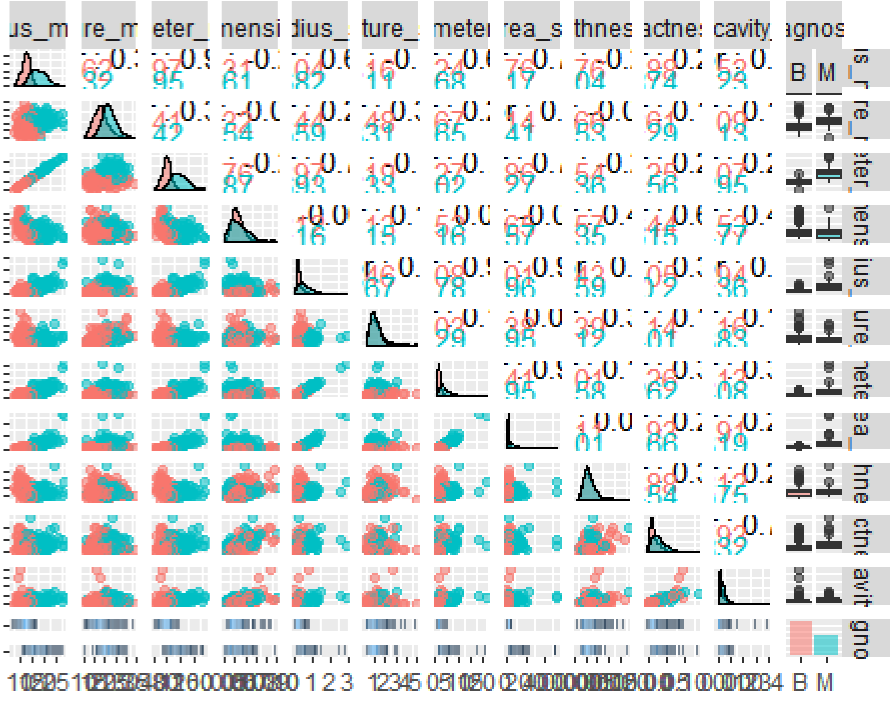
Rattle 2018-Nov-01 14:32:06 tsraj




Cost Curve Decision Tree CancerData.csv
Cost Curve Extreme Boost CancerData.csv
Cost Curve Random Forest CancerData.csv
Cost Curve Linear CancerData.csv
Cost Curve Neural Net CancerData.csv
FPR
FNR
Predict +ve
Predict -ve
Normalized expected cost
Probability cost function
0.0
0.2
0.4
0.6
0.8
1.0


s_r
ens
ius_
ure_
nete
ea_
nne
ctne
avit
.po
netr
mer
s_w
e_w
eter
a_w
gno
B M


ius_m
ure_me
neter_r
ea_me
nness_
ctness_
avity_m
.points
netry_r
agnosi
B
M


us_m
re_m
eter_
nensi
dius_
ture_
meter
rea_s
thnes
actne
cavity
agnos
B
M

R Script

```
setwd("C:/Users/tsraj/Desktop/Acadgild students
projects/project4")

library(readr)

CancerData <- read_csv("CancerData.csv")

print(paste("rows:", nrow(df), "cols:", ncol(CancerData)))

View(CancerData)

summary(CancerData)

dim(CancerData)

names(CancerData)

#CancerData<- CancerData[-1]

CancerData$diagnosis <- factor(CancerData$diagnosis, levels =
c("B", "M"),

                 labels = c("Benign", "Malignant"))

names(CancerData)

library(mice)

library(readr,dplyr)

library("ggplot2")

library("corrplot")

library("gridExtra")

library("pROC")

library("MASS")

library("caTools")

library("caret")
library(randomForest)
library(rpart)
library(rpart.plot)
library(rattle)
library(ggplot2)
library(Amelia)
library(class)
library(gmodels)
missmap(CancerData, main="Missing Data Map", col=c("#FF4081", "#3F51B5"),
      legend=FALSE)
data<-CancerData
data[,33]<-NULL

barplot(table(data$diagnosis), xlab = "Type of tumor", ylab="Numbers per type")

str(data)
any(is.na(data))
# visualize the missing values using the missing map from the Amelia package
missmap(data,col=c("yellow","red"))
data$diagnosis<-as.factor(data$diagnosis)
summary(data)
```

```
qplot(radius_mean, data=data, colour=diagnosis, geom="density",
      main="Radius mean for each tumor type")
qplot(smoothness_mean, data=data, colour=diagnosis,
geom="density",
      main="Smoothness mean for each tumor type")
qplot(concavity_mean, data=data, colour=diagnosis,
geom="density",
      main="Concavity mean for each tumor type")
qplot(area_worst , data=data, colour=diagnosis, geom="density",
      main="area worst for each tumor type")

# Looking at distribution for area.mean variable
plot.new()
hist(CancerData$area_mean,
     main = 'Distribution of Cell Area Means',
     xlab = 'Mean Area',
     col = 'green')
#we find that the data is imbalanced and also there is a lot of
corelation between the attributes
## we find that there are no missing values
## we find that data is little unbalanced
prop.table(table(data$diagnosis))
## we then show some correlation
corr_mat<-cor(data[,3:ncol(data)])
```

```
corrplot(corr_mat)


plot.new()

plot(data$area_mean ~data$concavity_mean)

title('Basic Scatterplot')

ggplot(data, aes(x=data$area_worst)) + geom_histogram(binwidth = 1, fill = "yellow", color = "black")

ggplot(data, aes(x=data$area_mean)) + geom_histogram(binwidth = 1, fill = "green", color = "red")


#Modelling

#We are going to get a training and a testing set to use when building some models:

set.seed(1234)

data_index<-createDataPartition(data$diagnosis,p=0.75,list = FALSE)

train_data<-data[data_index,-1]

test_data<-data[data_index,-1]


## Applying learning models

fitControl <- trainControl(method="cv",

                    number = 5,

                    preProcOptions = list(thresh = 0.99), # threshold for pca preprocess

                    classProbs = TRUE,
                        summaryFunction = twoClassSummary)
#Model1: Random Forest
#Building the model on the training data
## random forest
model_rf <- train(diagnosis~.,
                train_data,
                method="ranger",
                metric="ROC",
                #tuneLength=10,
                #tuneGrid = expand.grid(mtry = c(2, 3, 6)),
                preProcess = c('center', 'scale'),
                trControl=fitControl)

#Testing on the testing data
## testing for random forets
pred_rf <- predict(model_rf, test_data)
cm_rf <- confusionMatrix(pred_rf, test_data$diagnosis, positive =
"M")
cm_rf
# We find the accuracy of the model is 100%
#Random forest model- takes decision trees and averages them
normalize<-function(x){return((x-min(x))/(max(x)-min(x)))}
data$diagnosis<-as.numeric(data$diagnosis)
```

```
data_n<-as.data.frame(lapply(data,normalize))

traindata_n<--data_n[1:426,]

testdata_n<-data_n[427:569,]

rf <- randomForest(diagnosis ~., data= traindata_n, ntree =300,
mtry = 5, importance = TRUE)

print(rf)

plot.new()

varImpPlot(rf, type = 1, pch =8, col = 2, cex =0.8, main =
"cancerdata")

abline(v= 45, col= "red")

library(party)

#cf1 <- cforest(diagnosis ~ . , data=traindata_n ,
control=fitControl(mtry=5,ntree=300)) # fit the random forest


#varimp(cf1) # get variable importance, based on mean decrease in
accuracy


#varimp(cf1, conditional=TRUE)  # conditional=True, adjusts for
correlations between predictors


#varimpAUC(cf1)  # more robust towards class imbalance.

library(Boruta)

# Decide if a variable is important or not using Boruta
```

```
boruta_output <- Boruta( diagnosis~ ., data=na.omit(train_data), doTrace=2)  # perform Boruta search

boruta_signif <- names(boruta_output$finalDecision[boruta_output$finalDecision %in% c("Confirmed", "Tentative")])

boruta_signif

#Model2: Naive Bayes

#Building and testing the model

model_nb <- train(diagnosis~.,
           train_data,
           method="nb",
           metric="ROC",
           preProcess=c('center', 'scale'),
           trace=FALSE,
           trControl=fitControl)

## predicting for test data

pred_nb <- predict(model_nb, test_data)

cm_nb <- confusionMatrix(pred_nb, test_data$diagnosis, positive = "M")

cm_nb


#Accuracy of the model is 93.9%

#Model3: glm

#Building and testing the model
```

```
model_glm <- train(diagnosis~.,
            train_data,
            method="glm",
            metric="ROC",
            preProcess=c('center', 'scale'),
            trace=FALSE,
            trControl=fitControl)

## predicting for test data
pred_glm <- predict(model_glm, test_data)
cm_glm <- confusionMatrix(pred_glm, test_data$diagnosis, positive
= "M")
cm_glm
#Accuracy of the model is 98.3%
#algorithm for decision tree
library(C50)
data$diagnosis<-as.factor(data$diagnosis)
tree <- C5.0( diagnosis~., data = data)
summary(tree)
plot.new()
plot(tree)
results <- C5.0(diagnosis ~., data = data, rules = TRUE)
summary(results)
```

```
data<-as.data.frame(data)

library(rpart)

tree<-rpart(diagnosis~.,data =train_data,method="class")

plot(tree)

text(tree, pretty=0)

library(rattle)

library(rpart.plot)

library(RColorBrewer)

plot.new()

fancyRpartPlot(tree)

plot.new()

printcp(tree)

plotcp(tree)

ptree<- prune(tree, cp=
tree$cptable[which.min(tree$cptable[,"xerror"]),"CP"])

plot.new()

fancyRpartPlot(ptree, uniform=TRUE,main="Pruned Classification
Tree")

library(rpart)

fit1 <- rpart(diagnosis~.,data=train_data)

fit1

summary(fit1)

#Kernlab Classification

require(kernlab)
```

```
installed.packages("kernlab")

library(kernlab)

data_classifier<-ksvm(diagnosis ~., data =train_data ,
kernel='vanilladot')

data_classifier

data_predictions<-predict(data_classifier,test_data)

head(data_predictions)

table(data_predictions, test_data$diagnosis)

agreement<-data_predictions == test_data$diagnosis

table(agreement)

prop.table(table(agreement))

agreement

set.seed(12345)

data_classifier_rbf<-ksvm(diagnosis ~., data = train_data,
kernel='rbfdot')

data_predictions_rbf<-predict(data_classifier_rbf,test_data)

agreement_rbf<-data_predictions_rbf == test_data$diagnosis

table(agreement_rbf)

prop.table(table(agreement_rbf))



# logistic regression model:

fit <- glm(diagnosis~.,data = train_data,family =
binomial(link='logit'))
```

```
summary(fit)
library(MASS)
step_fit <- stepAIC(fit,method='backward')
summary(step_fit)
confint(step_fit)
#ANOVA on base model
anova(fit,test = 'Chisq')
#ANOVA from reduced model after applying the Step AIC
anova(step_fit,test = 'Chisq')

#plot the fitted model
plot.new()
plot(fit$fitted.values)
pred_link <- predict(fit,newdata = test_data,type = 'link')
#check for multicollinearity
library(car)
vif(fit)
vif(step_fit)
pred <- predict(fit,newdata =test_data ,type ='response')
#check the AUC curve
library(pROC)
g <- roc(diagnosis ~ pred, data = test_data)
g
```

```
plot.new()
plot(g)
library(caret)
#with default prob cut 0.50
test_data$pred_diagnosis <- ifelse(pred<0.5,'yes','no')

table(test_data$pred_diagnosis,test_data$diagnosis)


#training split of diagnosis classes
round(table(train_data$diagnosis)/nrow(train_data),2)*100
# test split of diagnosis
round(table(test_data$diagnosis)/nrow(test_data),2)*100
#predicted split of diagnosis
round(table(test_data$pred_diagnosis)/nrow(test_data),2)*100
#create confusion matrix
#confusionMatrix(test_data$diagnosis,test_data$pred_diagnosis)
#how do we create a cross validation scheme
control <- trainControl(method = 'repeatedcv',
                        number = 10,
                        repeats = 3)
seed <-7
metric <- 'Accuracy'
set.seed(seed)
```

```
fit_default <- train(diagnosis~.,
             data = train_data,
             method = 'glm',
             metric =metric ,
             trControl = control)
print(fit_default)
library(caret)
varImp(step_fit)
varImp(fit_default)
library(woe)

library(riv)
train_data<-as.data.frame(train_data)
iv_df <- iv.mult(train_data, y="diagnosis", summary=TRUE,
verbose=TRUE)
iv_df
iv <- iv.mult(train_data, y="diagnosis", summary=FALSE,
verbose=TRUE)
# Plot information value summary

iv.plot.summary(iv_df)



#4. MARS (earth package)
```

```
#The earth package implements variable importance based on Generalized cross validation (GCV),

#number of subset models the variable occurs (nsubsets) and residual sum of squares (RSS).

library(earth)

marsModel<-earth(diagnosis~ ., data=data) # build model

ev <- evimp (marsModel) # estimate variable importance

ev

plot.new()

plot (ev)
```