Data Mining with R

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Import libs:

```
library(caret)
library(data.table)
library(dplyr)
library(PerformanceAnalytics)
library(rpart.plot)
```

Data Overview

Data Set Characteristics:	Number of Instances:	Attribute Characteristics:	Number of Attributes:	Associated Tasks:
Multivariate	1372	Real	5	Classification

Dataset information: Data were extracted from images that were taken from genuine and forged banknote-like specimens. For digitization, an industrial camera usually used for print inspection was used. The final images have 400 x 400 pixels. Due to the object lens and distance to the investigated object gray-scale pictures with a resolution of about 660 dpi were gained. Wavelet Transform tool were used to extract features from images.

Attribute information:

1. variance of Wavelet Transformed image (type: continuous)

2. skewness of Wavelet Transformed image (type: continuous)
3. curtosis of Wavelet Transformed image (type: continuous)
4. entropy of image (type: continuous)
5. class (type: integer)

Data source: https://archive.ics.uci.edu/ml/datasets/banknote+authentication

Load `data_banknote_authentication.txt` file:

```
url = paste('https://archive.ics.uci.edu/ml/machine-learning-databases/00267/',
            'data_banknote_authentication.txt', sep='')
df = data.frame(fread(url))
names(df) = c('variance', 'skewness', 'curtosis', 'entropy', 'class')
```

Check size of `df` dataframe:

```
nrow(df)
```

Output:

```
1372
```

Show the first part of `df` dataframe:

```
head(df, 5)
```

variance	skewness	curtosis	entropy	class
3.62160	8.6661	-2.8073	-0.44699	0
4.54590	8.1674	-2.4586	-1.46210	0
3.86600	-2.6383	1.9242	0.10645	0
3.45660	9.5228	-4.0112	-3.59440	0
0.32924	-4.4552	4.5718	-0.98880	0

Show the last part of `df` dataframe:

```
tail(df, 5)
```

	variance	skewness	curtosis	entropy	class
1368	0.40614	1.34920	-1.4501	-0.55949	1
1369	-1.38870	-4.87730	6.4774	0.34179	1
1370	-3.75030	-13.45860	17.5932	-2.77710	1
1371	-3.56370	-8.38270	12.3930	-1.28230	1
1372	-2.54190	-0.65804	2.6842	1.19520	1

Summary Statistics

Mean

```
print(noquote(paste0('Mean. Variance of Wavelet Transformed image: ',
mean(df$variance))))
print(noquote(paste0('Mean. Skewness of Wavelet Transformed image: ',
mean(df$skewness))))
print(noquote(paste0('Mean. Curtosis of Wavelet Transformed image: ',
mean(df$curtosis))))
print(noquote(paste0('Mean. Entropy of image: ', mean(df$entropy))))
```

Output:

```
[1] Mean. Variance of Wavelet Transformed image: 0.433735257069971
[1] Mean. Skewness of Wavelet Transformed image: 1.92235312063936
[1] Mean. Curtosis of Wavelet Transformed image: 1.39762711726676
[1] Mean. Entropy of image: -1.19165652004373
```

Median

```
print(noquote(paste0('Median. Variance of Wavelet Transformed image: ',
                     median(df$variance))))
print(noquote(paste0('Median. Skewness of Wavelet Transformed image: ',
                     median(df$skewness))))
print(noquote(paste0('Median. Curtosis of Wavelet Transformed image: ',
                     median(df$curtosis))))
print(noquote(paste0('Median. Entropy of image: ', median(df$entropy))))
```

Output:

```
[1] Median. Variance of Wavelet Transformed image: 0.49618
[1] Median. Skewness of Wavelet Transformed image: 2.31965
[1] Median. Curtosis of Wavelet Transformed image: 0.61663
[1] Median. Entropy of image: -0.58665
```

All-in-One

```
print(noquote('Summary:'))
summary(select(df, -class))
```

Output:

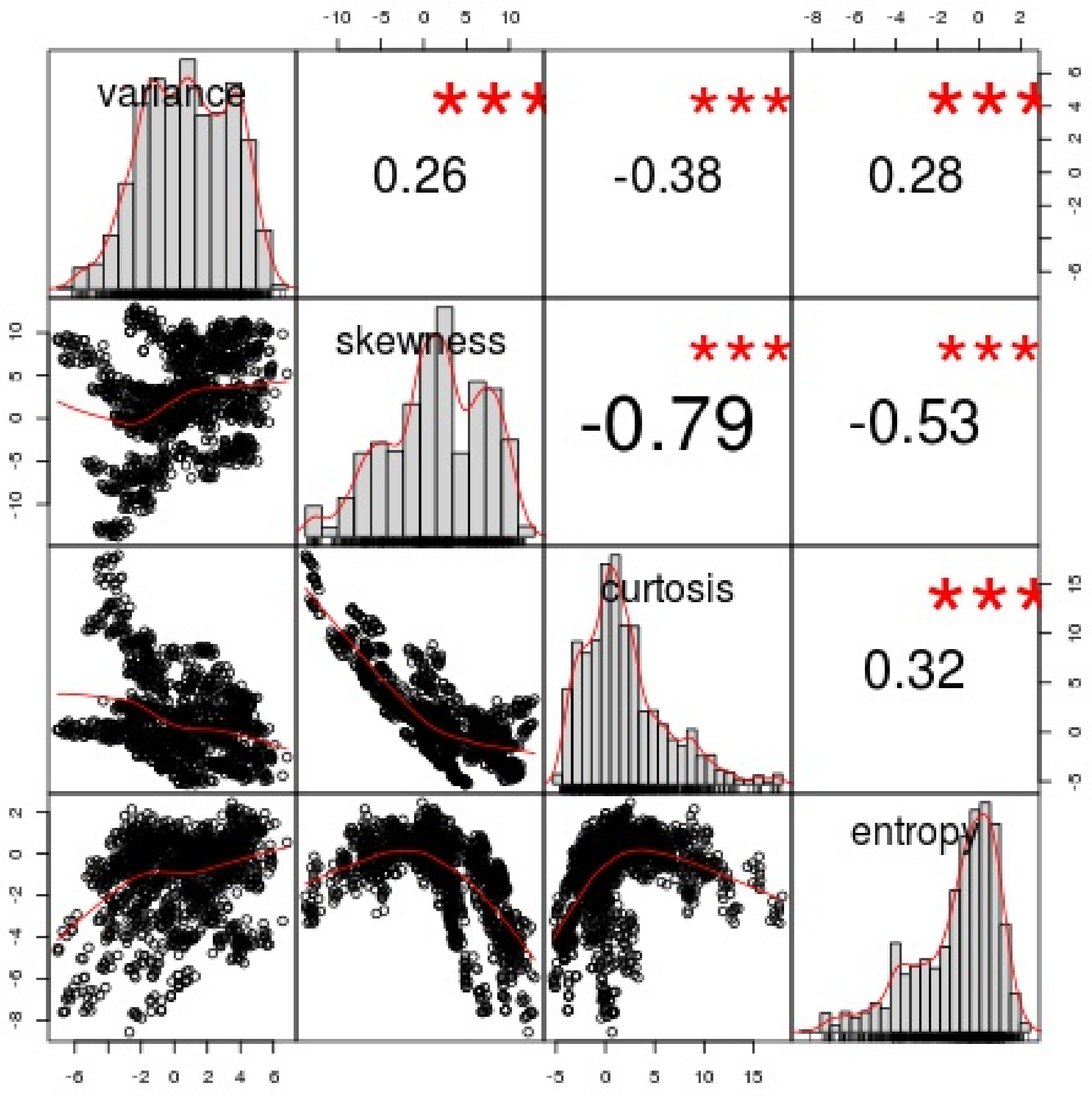
```
[1] Summary:

   variance          skewness          curtosis          entropy
Min.   :-7.0421   Min.   :-13.773   Min.   :-5.2861   Min.   :-8.5482
1st Qu.:-1.7730   1st Qu.: -1.708   1st Qu.:-1.5750   1st Qu.:-2.4135
Median : 0.4962   Median :  2.320   Median : 0.6166   Median :-0.5867
Mean   : 0.4337   Mean   :  1.922   Mean   : 1.3976   Mean   :-1.1917
3rd Qu.: 2.8215   3rd Qu.:  6.815   3rd Qu.: 3.1793   3rd Qu.: 0.3948
Max.   : 6.8248   Max.   : 12.952   Max.   :17.9274   Max.   : 2.4495
```

Correlation

```
cor(df)
```

	variance	skewness	curtosis	entropy	class
variance	1.0000000	0.2640255	-0.3808500	0.27681670	-0.72484314
skewness	0.2640255	1.0000000	-0.7868952	-0.52632084	-0.44468776
curtosis	-0.3808500	-0.7868952	1.0000000	0.31884089	0.15588324
entropy	0.2768167	-0.5263208	0.3188409	1.00000000	-0.02342368
class	-0.7248431	-0.4446878	0.1558832	-0.02342368	1.00000000

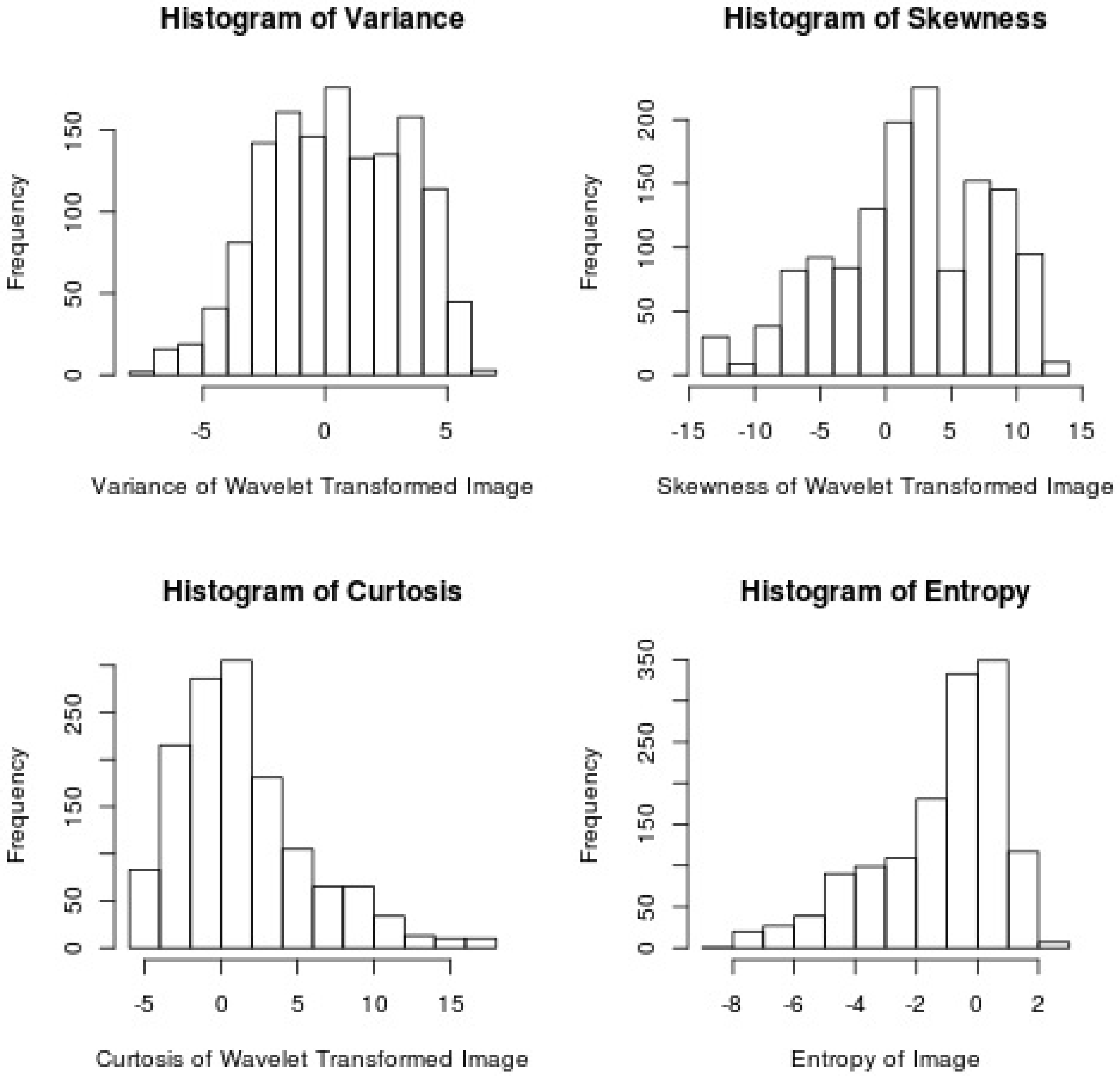
```
chart.Correlation(select(df, -class), histogram=TRUE)
```



Graphics

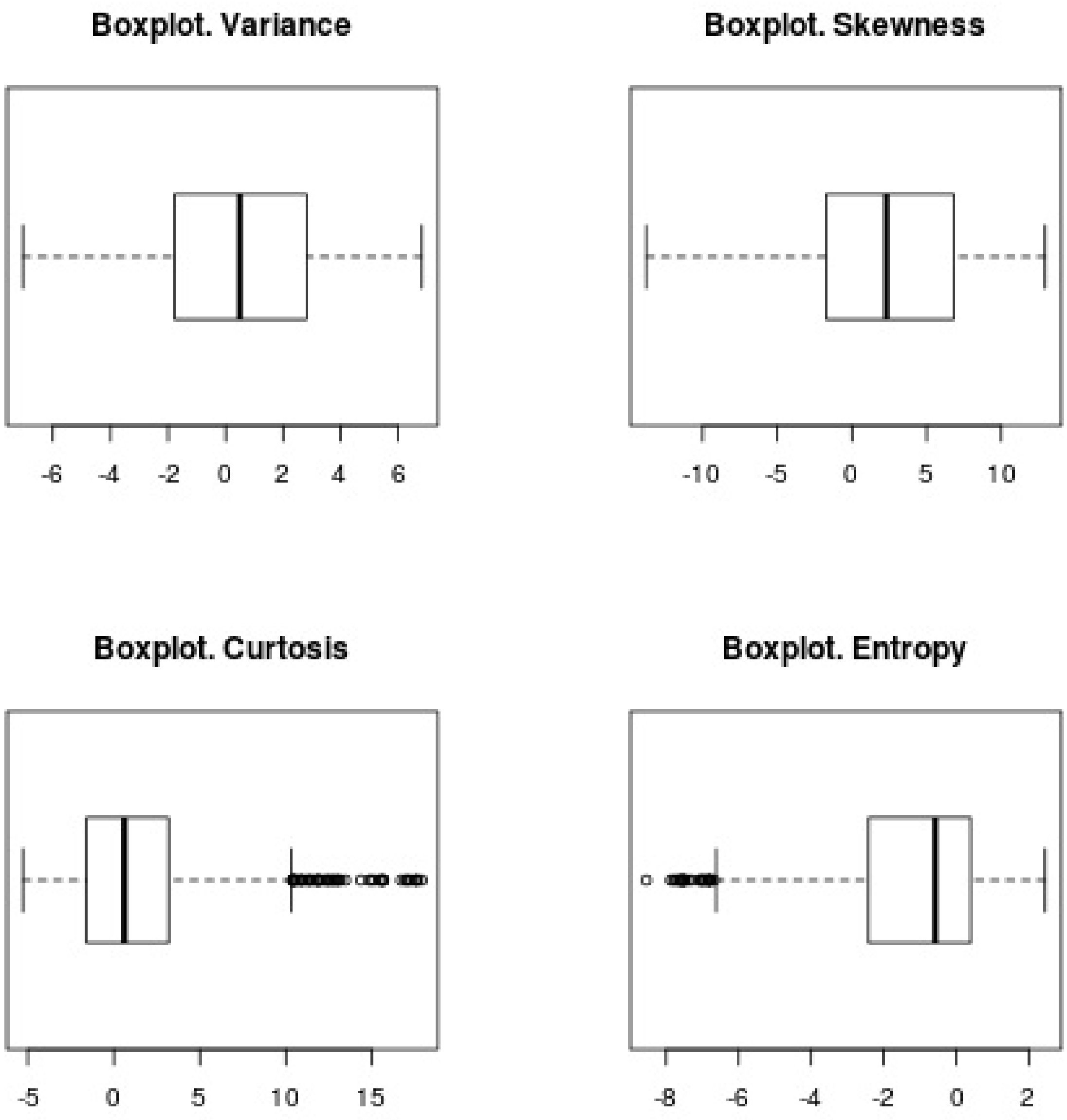
Histograms

```
par(mfrow=c(2,2))
hist(df$variance, main='Histogram of Variance',
     xlab='Variance of Wavelet Transformed Image')
hist(df$skewness, main='Histogram of Skewness',
     xlab='Skewness of Wavelet Transformed Image')
hist(df$curtosis, main='Histogram of Curtosis',
     xlab='Curtosis of Wavelet Transformed Image')
hist(df$entropy, main='Histogram of Entropy',
     xlab='Entropy of Image')
```



Boxplots

```
par(mfrow=c(2,2))
boxplot(df$variance, data=df, main='Boxplot. Variance', horizontal=TRUE)
boxplot(df$skewness, data=df, main='Boxplot. Skewness', horizontal=TRUE)
boxplot(df$curtosis, data=df, main='Boxplot. Curtosis', horizontal=TRUE)
boxplot(df$entropy, data=df, main='Boxplot. Entropy', horizontal=TRUE)
```



Near Zero Variance Predictors

```
nearZeroVar(select(df, -class), saveMetrics=TRUE)
```

	freqRatio	percentUnique	zeroVar	nzv
variance	1.25	97.52187	FALSE	FALSE
skewness	1.20	91.54519	FALSE	FALSE
curtosis	1.00	92.56560	FALSE	FALSE
entropy	1.00	84.25656	FALSE	FALSE

Linear Combinations

```
findLinearCombos(select(df, -class))
```

Output:

```
$linearCombos
list()

$remove
NULL
```

Highly Correlated Variables

```
df$class = as.character(ifelse(df$class=='1', 'Y', 'N'))
df2 = select(df, -class)
cor_matrix = cor(df2)
print(noquote('Highly correlated variables:'))
summary(cor_matrix[upper.tri(cor_matrix)]) # upper triangular part of a matrix
```

Output:

```
[1] Highly correlated variables:

    Min.  1st Qu.   Median     Mean  3rd Qu.     Max. 
-0.78690 -0.48995 -0.05841 -0.13906  0.27362  0.31884 
```

```
high_cor_var = findCorrelation(cor_matrix, cutoff = 0.75) # check var above
0.75
print(noquote(paste0('Highly correlated variables: ', names(df2)
[high_cor_var])))
```

Output:

```
[1] Highly correlated variables: skewness
```

Delete highly correlated skewness column from dataframe:

```
df2 = select(df2, -skewness)
```

```
cor_matrix = cor(df2)
print(noquote('Highly correlated variables:'))
summary(cor_matrix[upper.tri(cor_matrix)]) # upper triangular part of a matrix
df = cbind.data.frame(df2, class = df$class) # add class
```

Output:

```
[1] Highly correlated variables:

    Min.  1st Qu.   Median     Mean  3rd Qu.     Max. 
-0.38085 -0.05202  0.27682  0.07160  0.29783  0.31884 
```

Distribution

```
print(noquote('Distribution:'))
table(df$class)
```

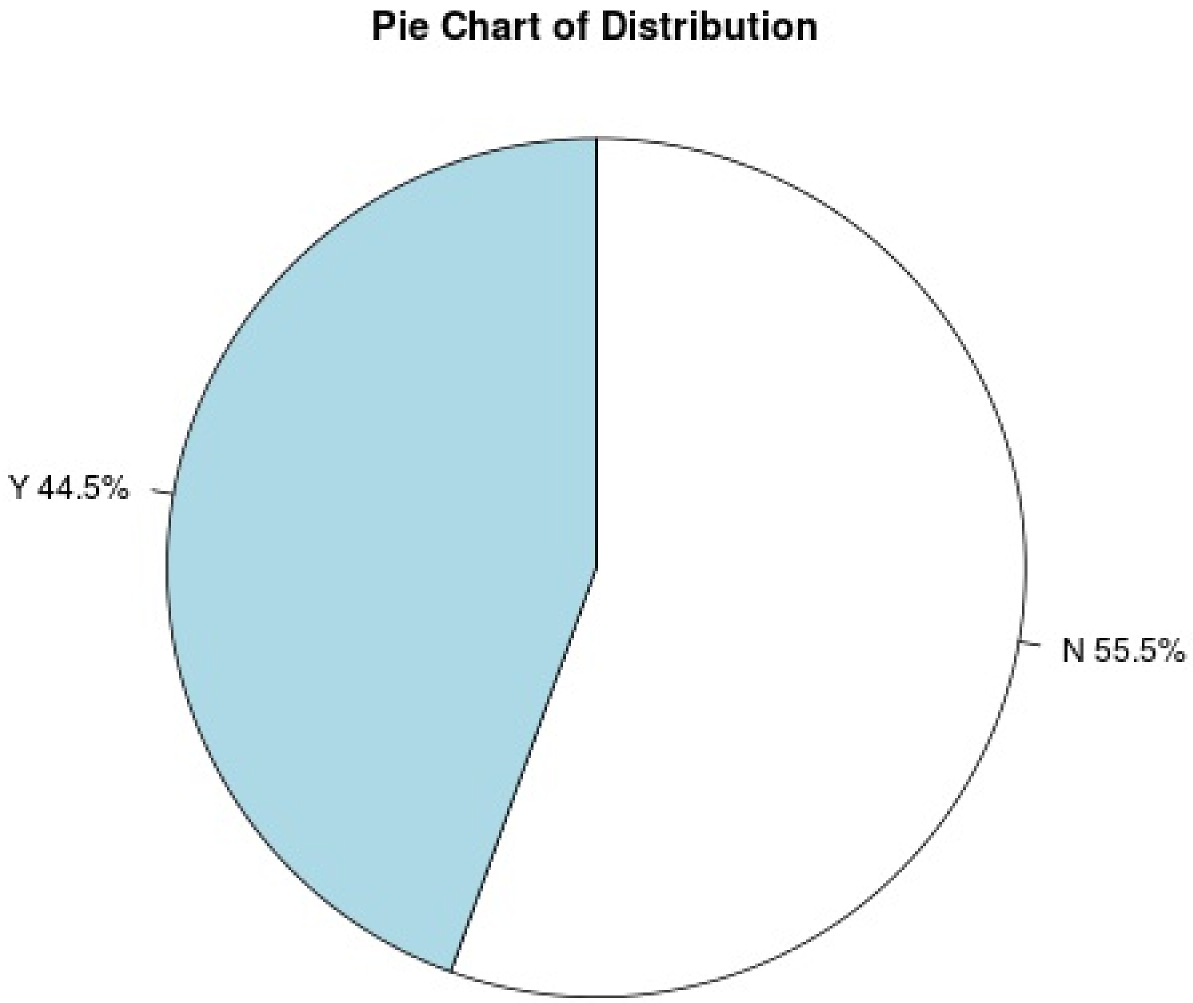
Output:

```
[1] Distribution:

  N   Y 
762 610 
```

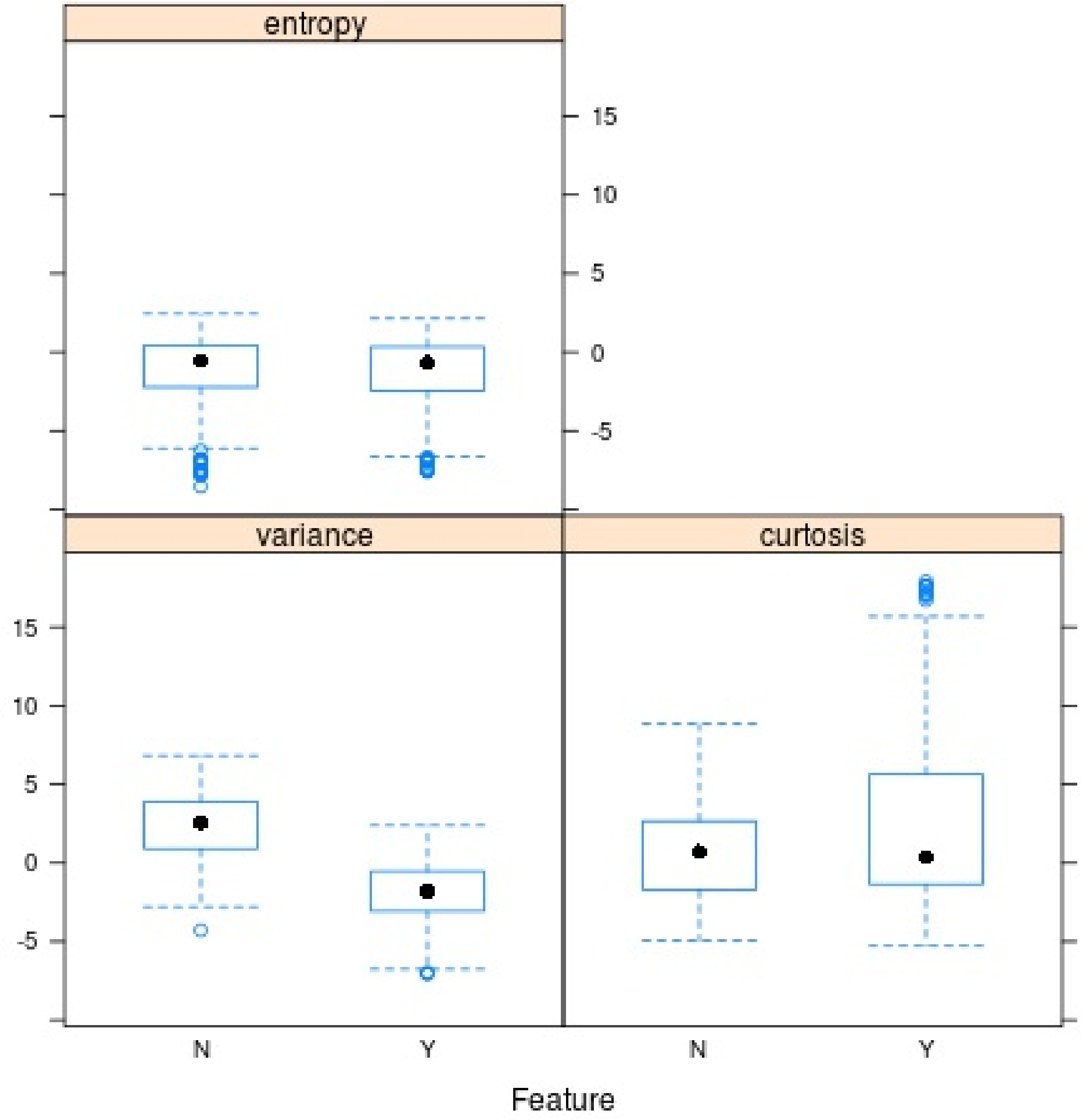
```
class_freq = data.frame(table(df$class))
names(class_freq) = c('class', 'freq')
percent_chart = cbind(class_freq,
                      percent=round((class_freq$freq/sum(class_freq$freq))*100,
1))
percent_chart
```

class	freq	percent
N	762	55.5
Y	610	44.5

```
slices = percent_chart$percent
lbls = c('N', 'Y')
pct = round(slices/sum(slices)*100, 1)
lbls = paste(lbls, pct) # add values of pct to labels
lbls = paste(lbls, '%', sep='') # add % char to labels
pie(slices, labels=lbls, radius=1, main='Pie Chart of Distribution',
    clockwise=TRUE)
```

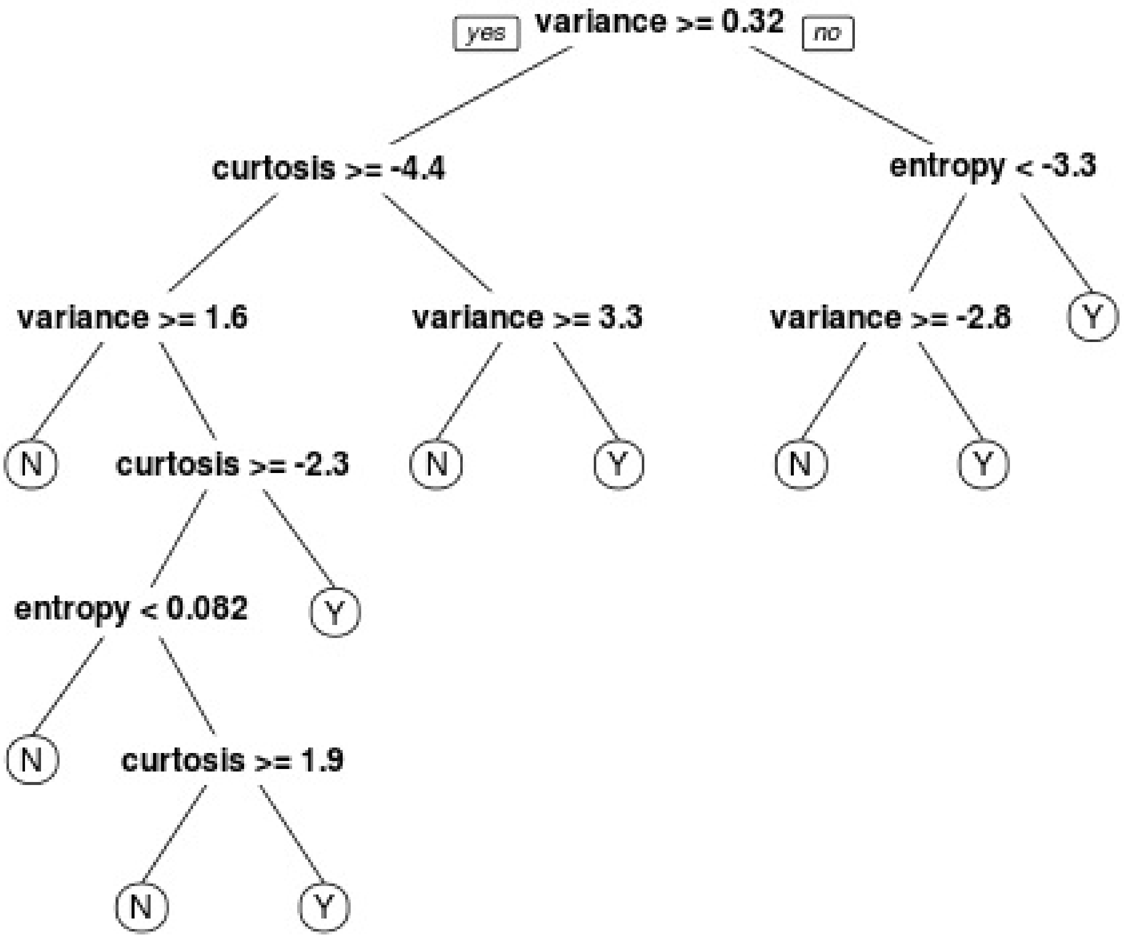


```
featurePlot(x=select(df, -class), y=df$class, plot='box')
```

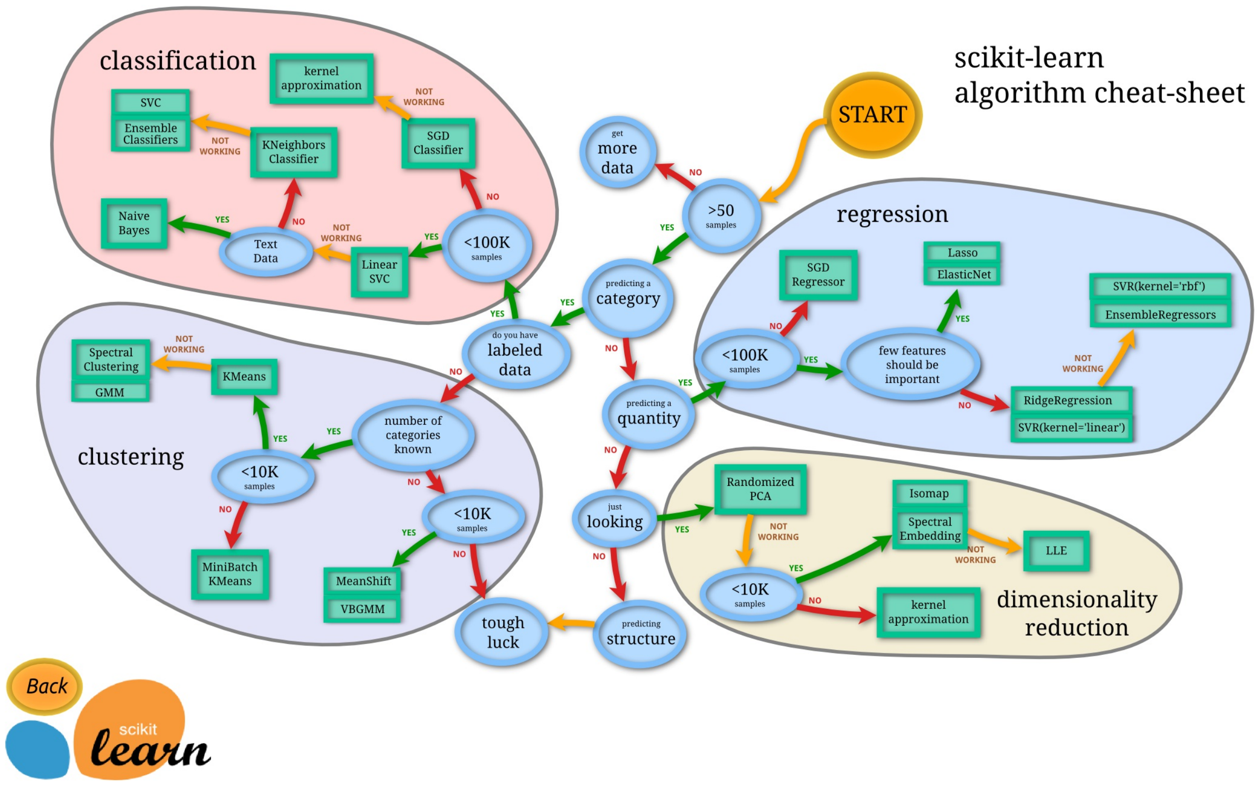


Decision Tree

```
rtree_set = rpart(class ~ ., df)
prp(rtree_set)
```



Classification



Split the data to train and test sets:

```
train_ind = createDataPartition(df$class, p=0.7, list=FALSE)
data_train = data.frame(df[train_ind, ])
data_test = data.frame(df[-train_ind, ])
print(noquote('Train:'))
table(data_train$class)
print(noquote('Test:'))
table(data_test$class)
```

Output:

```
[1] Train:

  N   Y 
534 427 

[1] Test:

  N   Y 
228 183 
```

Choose validation method for the test of model:

```
valid_par = trainControl(method='repeatedcv', number=5, repeats=10, p=0.70,
preProc='range')
```

SVM

```
mod_svm = train(class ~ ., data=data_train, trControl=valid_par,
method='svmRadial')
mod_svm
```

Output:

```
Support Vector Machines with Radial Basis Function Kernel

961 samples
  3 predictors
  2 classes: 'N', 'Y'

No pre-processing
Resampling: Cross-Validated (5 fold, repeated 10 times)
Summary of sample sizes: 768, 769, 770, 769, 768, 770, ...
Resampling results across tuning parameters:

  C     Accuracy   Kappa
  0.25  0.9785620  0.9568214
  0.50  0.9807452  0.9612074
  1.00  0.9815764  0.9628818

Tuning parameter 'sigma' was held constant at a value of 0.8345372
Accuracy was used to select the optimal model using the largest value.
The final values used for the model were sigma = 0.8345372 and C = 1.
```

KNN

```
mod_knn = train(class ~. , data=data_train, trControl=valid_par, method='knn')
mod_knn
```

Output:

```
k-Nearest Neighbors

961 samples
  3 predictors
  2 classes: 'N', 'Y'

No pre-processing
Resampling: Cross-Validated (5 fold, repeated 10 times)
Summary of sample sizes: 768, 769, 769, 769, 769, 768, ...
Resampling results across tuning parameters:

  k  Accuracy   Kappa
  5  0.9761700  0.9519131
  7  0.9766871  0.9529962
  9  0.9748131  0.9492504

Accuracy was used to select the optimal model using the largest value.
The final value used for the model was k = 7.
```

Show summary:

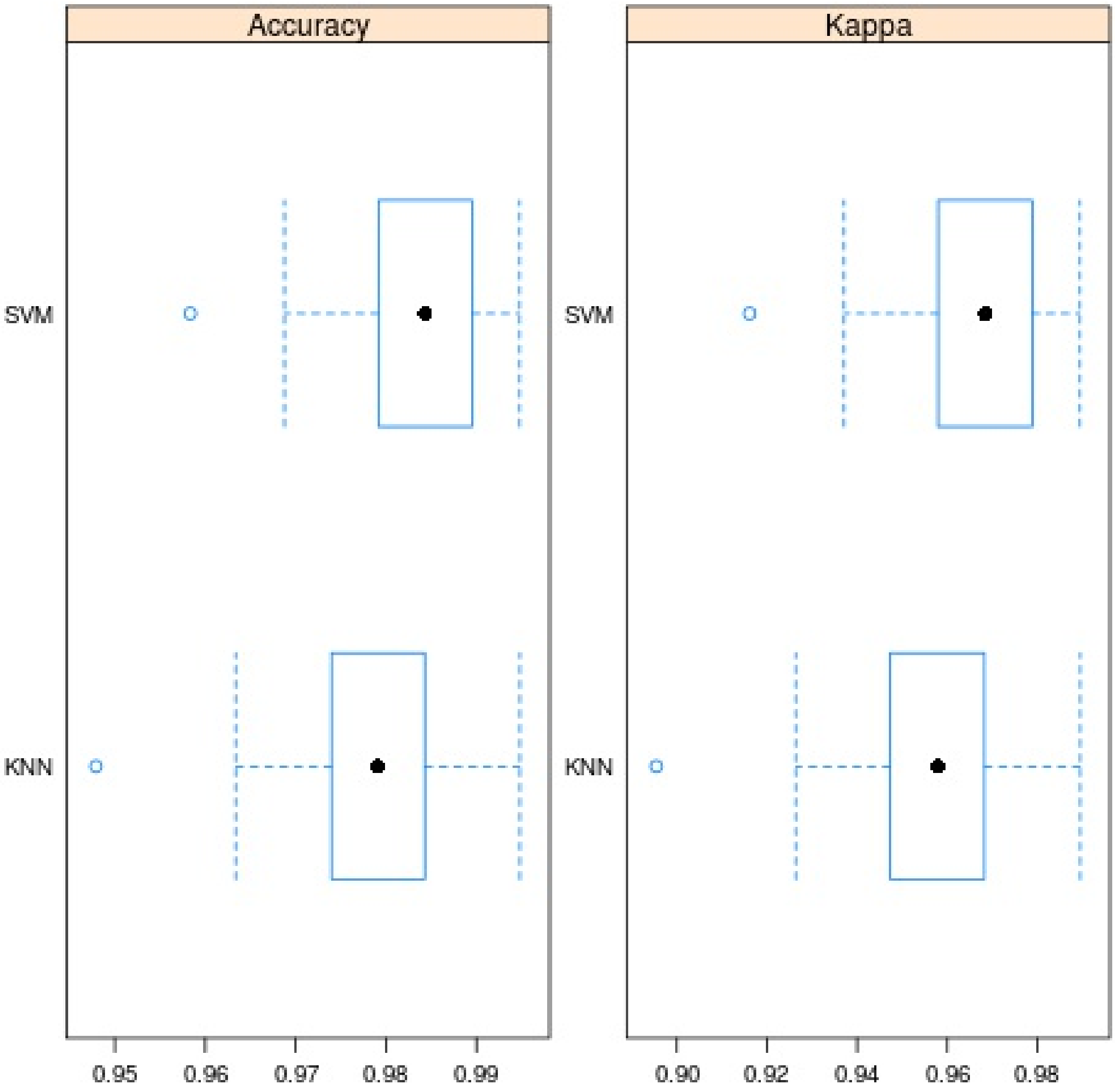
```
print(noquote('Summary:'))
mod_results = resamples(list(SVM=mod_svm, KNN=mod_knn))
summary(mod_results)
```

Output:

```
[1] Summary:

Call:
summary.resamples(object = mod_results)

Models: SVM, KNN
Number of resamples: 50

Accuracy
         Min.   1st Qu.    Median      Mean   3rd Qu.      Max. NA's
SVM 0.9633508 0.9740933 0.9843750 0.9815764 0.9882606 1.0000000    0
KNN 0.9581152 0.9687905 0.9740933 0.9766871 0.9843750 0.9947917    0

Kappa
         Min.   1st Qu.    Median      Mean   3rd Qu.      Max. NA's
SVM 0.9264050 0.9478632 0.9684487 0.9628818 0.9762997 1.0000000    0
KNN 0.9157941 0.9372235 0.9476255 0.9529962 0.9684487 0.9894575    0
```

SVM vs KNN

```
bwplot(mod_results, scales=list(x=list(relation='free'),
y=list(relation='free')))
```



Test models:

```
test = select(data_test, -class)
test_sum = data_test$class
mod_predict_svm = predict(mod_svm, test)
print(noquote('SMV:'))
confusionMatrix(mod_predict_svm, test_sum)
mod_predict_knn = predict(mod_knn, test)
print(noquote('KNN:'))
confusionMatrix(mod_predict_knn, test_sum)
```

Output:

```
[1] SMV:

Confusion Matrix and Statistics
```

```
          Reference
Prediction   N   Y
         N 222   1
         Y   6 182

               Accuracy : 0.983
                 95% CI : (0.9652, 0.9931)
    No Information Rate : 0.5547
    P-Value [Acc > NIR] : <2e-16

                  Kappa : 0.9656
 Mcnemar's Test P-Value : 0.1306

            Sensitivity : 0.9737
            Specificity : 0.9945
         Pos Pred Value : 0.9955
         Neg Pred Value : 0.9681
             Prevalence : 0.5547
         Detection Rate : 0.5401
   Detection Prevalence : 0.5426
      Balanced Accuracy : 0.9841

       'Positive' Class : N

[1] KNN:

Confusion Matrix and Statistics

          Reference
Prediction   N   Y
         N 223   2
         Y   5 181

               Accuracy : 0.983
                 95% CI : (0.9652, 0.9931)
    No Information Rate : 0.5547
    P-Value [Acc > NIR] : <2e-16

                  Kappa : 0.9656
 Mcnemar's Test P-Value : 0.4497

            Sensitivity : 0.9781
            Specificity : 0.9891
         Pos Pred Value : 0.9911
         Neg Pred Value : 0.9731
             Prevalence : 0.5547
         Detection Rate : 0.5426
   Detection Prevalence : 0.5474
      Balanced Accuracy : 0.9836

       'Positive' Class : N
```