Assignment - III

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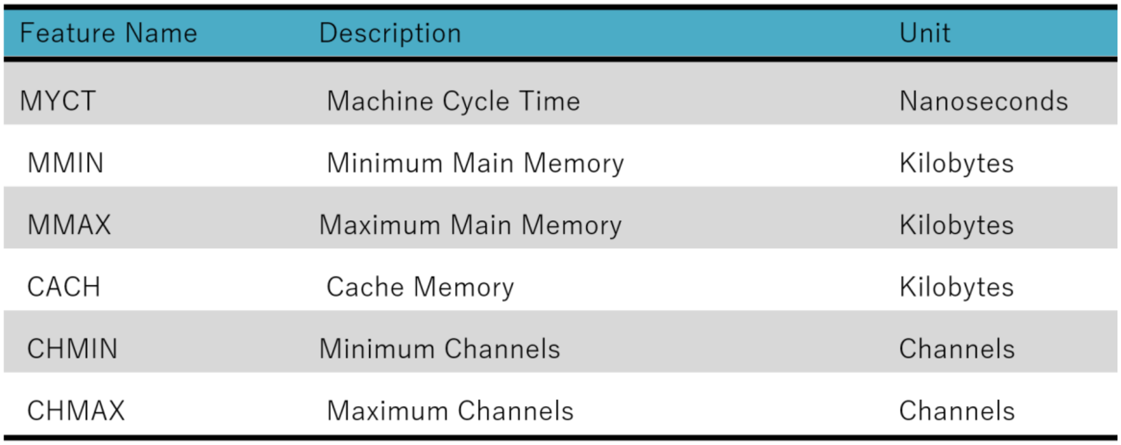
First Problem

The data on features given in the table below are collected to estimate the published relative performance (PRP) of a centralised processing unit. The data is given in the CPU_Data file.



Feature Name	Description	Unit
MYCT	Machine Cycle Time	Nanoseconds
MMIN	Minimum Main Memory	Kilobytes
MMAX	Maximum Main Memory	Kilobytes
CACH	Cache Memory	Kilobytes
CHMIN	Minimum Channels	Channels
CHMAX	Maximum Channels	Channels

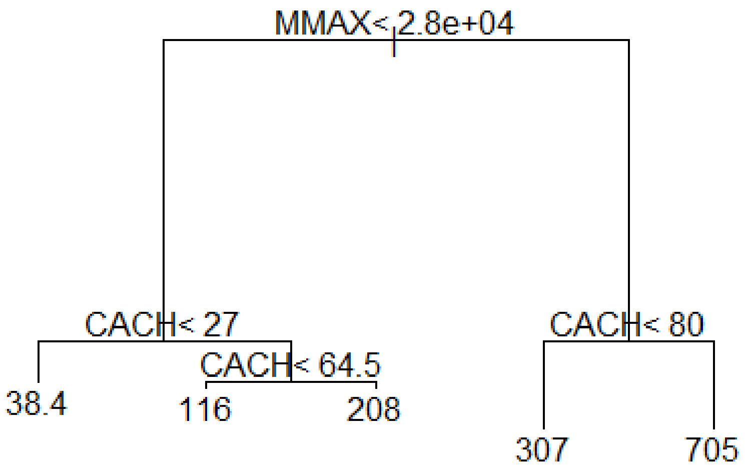
Load the Data

```
df<- readxl::read_excel("CPU_data.xlsx")

# Head of Data
attach(df)

# Head of Data
head(df)
```

```
## # A tibble: 6 × 7
##    MYCT  MMIN  MMAX  CACH CHMIN CHMAX   PRP
##   <dbl> <dbl> <dbl> <dbl> <dbl> <dbl> <dbl>
## 1   125   256  6000   256    16   128   198
## 2    29  8000 32000    32     8    32   269
## 3    29  8000 32000    32     8    32   220
## 4    29  8000 32000    32     8    32   172
## 5    29  8000 16000    32      8     16    132
## 6    26  8000 32000    64      8     32    318
```

a. Split the data randomly into training (80%) and test (20%). Develop a CART model for PRP using training data

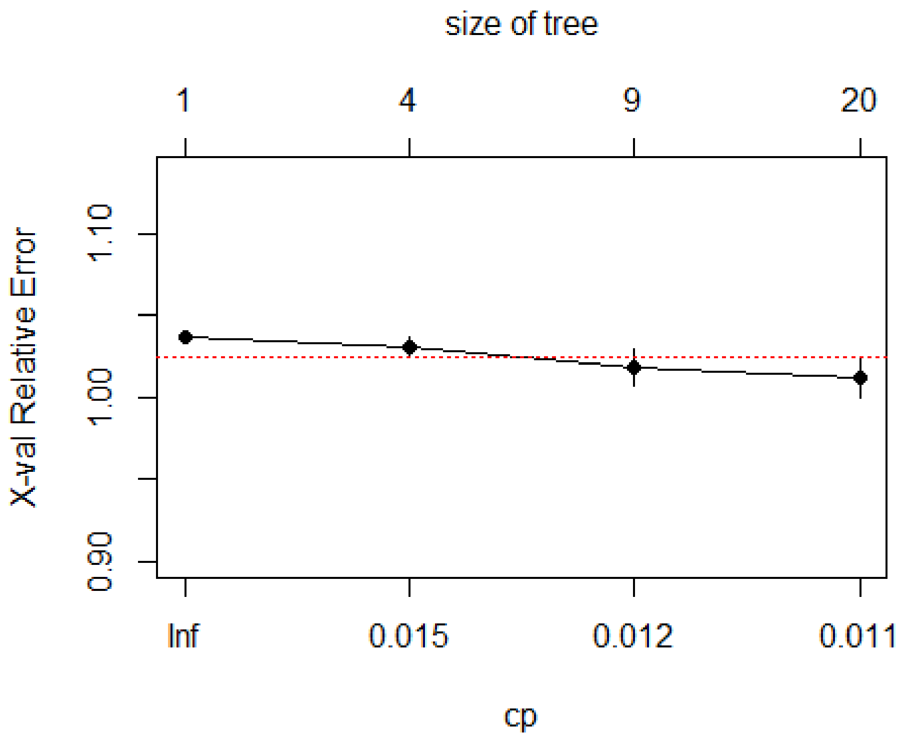
```
library(rpart)
library(caret)

## Loading required package: ggplot2

## Loading required package: lattice

set.seed(1)
indexes = createDataPartition(PRP, p = 0.80, list = F)
train = df[indexes, ]
test = df[-indexes, ]

train_x = train[, -7]
train_y = train[, 7]  # PRP

test_x = test[, -7]
test_y = test[, 7]  # PRP

dim(train_x)

## [1] 169   6

fit = rpart(PRP ~ ., data = train)


par(xpd = NA) # otherwise on some devices the text is clipped
plot(fit)
text(fit, digits = 3)
```



```
print(fit, digits = 2)

## n= 169
##
## node), split, n, deviance, yval
##       * denotes terminal node
##
##  1) root 169 5000000 110
##    2) MMAX< 2.8e+04 147  500000  61
##      4) CACH< 27 113   58000   38 *
##      5) CACH>=27 34  190000 140
##       10) CACH< 64 26   76000 120 *
##       11) CACH>=64 8   59000 210 *
##    3) MMAX>=2.8e+04 22 1800000 430
##      6) CACH< 80 15  290000 310 *
##      7) CACH>=80 7  760000 700 *
```

b. Show the cp plot and give the optimum cp value

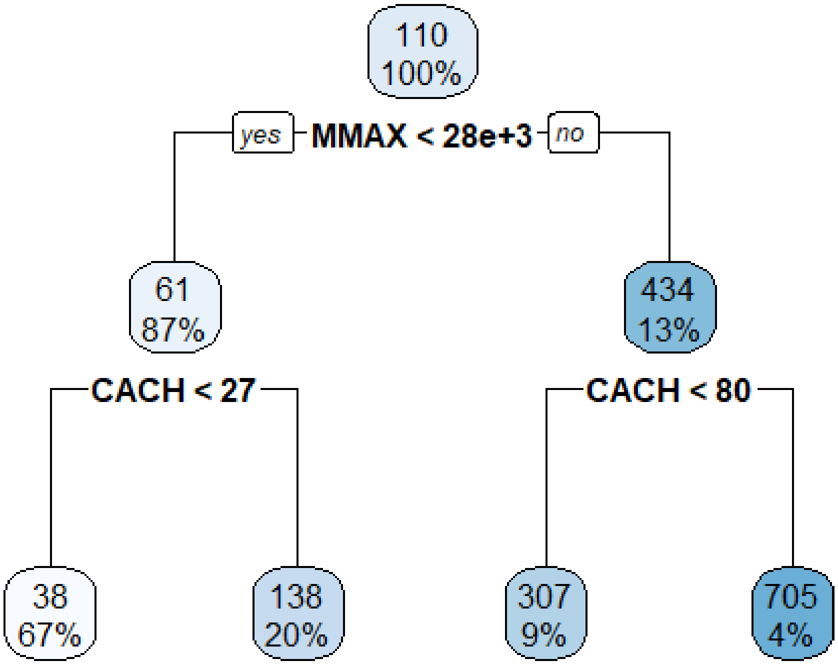
```
library(rpart.plot)
mymodel = rpart(PRP ~. ,data = train, method = 'class', control = rpart.contr
ol(minsplit = 2))

# Cross validation and identification of cp
plotcp(mymodel, pch = 19, col = "red")
```



Optimum cp = 0.019 Corresponding to minimum cross validation relative error

c. Display the best CART model obtained (rpart.plot) and give your interpretation

```
library(rpart.plot)
fit.pruned = prune(fit, cp = 0.019)

rpart.plot(fit.pruned)
```



d. Compute the mean square error (MSE) and root mean square error (RMSE) for training data. Is the model reasonably accurate?

```
pred_y_tr = predict(fit.pruned, train_x)
#Accuracy checking

#Next, we'll check the prediction accuracy with MSE, MAE, and RMSE metrics.

print(head(data.frame(train_y, pred_y_tr)))

##   PRP pred_y_tr
## 1 198  137.9118
## 2 269  307.4000
## 3 220  307.4000
## 4 132  137.9118
## 5 318  307.4000
## 6 367  307.4000

msetr = sapply((train_y - pred_y_tr)^2, mean, 2)

maetr = sapply(as.data.frame(train_y,  pred_y_tr), caret::MAE, 2)

rmsetr = sapply(as.data.frame(train_y,  pred_y_tr), caret::RMSE, 2)

tr_acc <- cat("MSE: ", msetr, "MAE: ", maetr, " RMSE: ", rmsetr)

## MSE:  458.2631 MAE:  107.8994  RMSE:  202.5156
```

e. Validate the model on test data. Compute MSE and RMSE on test data

```
pred_y = predict(fit.pruned, test_x)
#Accuracy checking

#Next, we'll check the prediction accuracy with MSE, MAE, and RMSE metrics.

print(head(data.frame(test_y, pred_y)))

##   PRP    pred_y
## 1 172 307.40000
## 2  40  38.40708
## 3  28  38.40708
## 4  31  38.40708
## 5  69  38.40708
## 6  33  38.40708

mse = sapply((test_y - pred_y)^2, mean, 2)

mae = sapply(as.data.frame(test_y,  pred_y), caret::MAE, 2)

rmse = sapply(as.data.frame(test_y,  pred_y), caret::RMSE, 2)

test_acc<- cat("MSE: ", mse, "MAE: ", mae, " RMSE: ", rmse)

## MSE:  529.3516 MAE:  85.55  RMSE:  131.649
```

f. Provide the comparison table of MSE & RMSE for training and test data. Give your comments on the model accuracy and generalizability?

```
data.frame(Errors = c("MSE", "MAE", "RMSE"),
           Training_accuracy = c(458.26, 107.89, 202.52),
           Test_accuracy = c(529.35, 85.55, 131.6)
  )

##   Errors Training_accuracy Test_accuracy
## 1    MSE            458.26        529.35
## 2    MAE            107.89         85.55
## 3   RMSE            202.52        131.60
```

g. Validate the model on test data? Compute mean square error and root mean square on test data. Give your comments on model generalizability.

h. Develop a model to predict PRP using the Bagging method.

```
library(randomForest)

## randomForest 4.7-1.1

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

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

```
mymodel = randomForest(PRP ~., data = train, mtry = 13, importance =  TRUE)
```

```
## Warning in randomForest.default(m, y, ...): invalid mtry: reset to within
valid
## range
```

```
mymodel
```

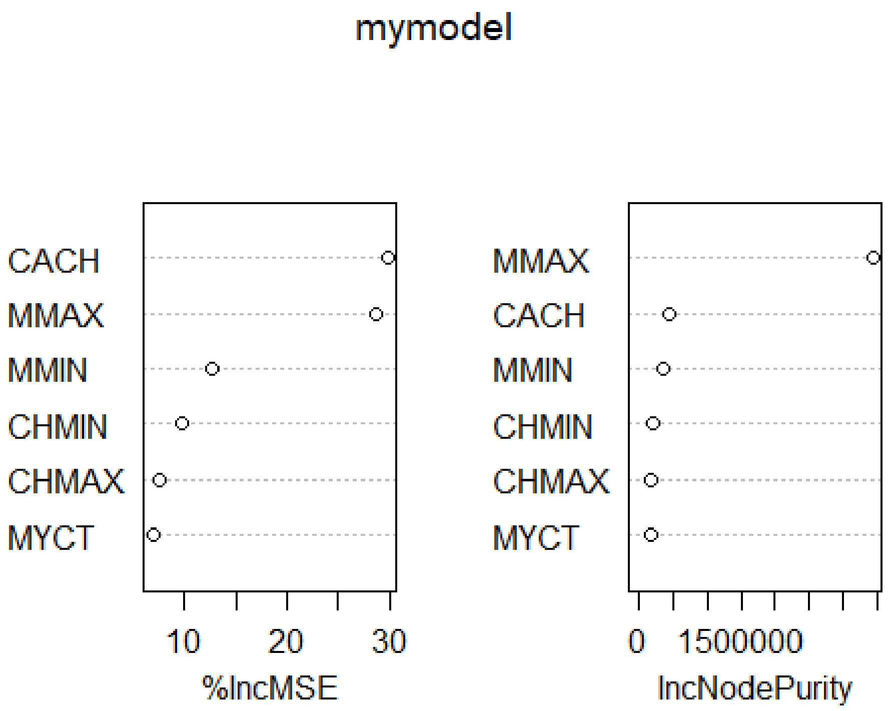
```
##
## Call:
##  randomForest(formula = PRP ~ ., data = train, mtry = 13, importance = TRU
E)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 6
##
##           Mean of squared residuals: 3468.082
##                     % Var explained: 88.19
```

i. Provide variable importance plot and give your comments?

```
importance(mymodel)
```

```
##         %IncMSE IncNodePurity
## MYCT   7.000670      162707.3
## MMIN  12.671986      358981.4
## MMAX  28.691670     3433065.4
## CACH  29.818329      446125.0
## CHMIN  9.734622      214210.2
## CHMAX  7.480474      184521.4
```

```
varImpPlot(mymodel)
```



j. Compute the R2, mean square error and root mean square on training data. Give your comments on model accuracy.

```
predtrain = predict(mymodel, newdata = train)
restrain = train$PRP - predtrain
mset = mean(restrain^2)

R2t<- R2(predtrain, train$PRP, form = "traditional")

rmset = sqrt(mse)
cat("MSE: ", mset," RMSE: ", rmset, "R2: ", R2t)

## MSE:  988.0823  RMSE:  23.00764 R2:  0.9663577
```

k. Validate the model on test data? Compute mean square error and root mean square on test data. Give your comments on model generalizability.

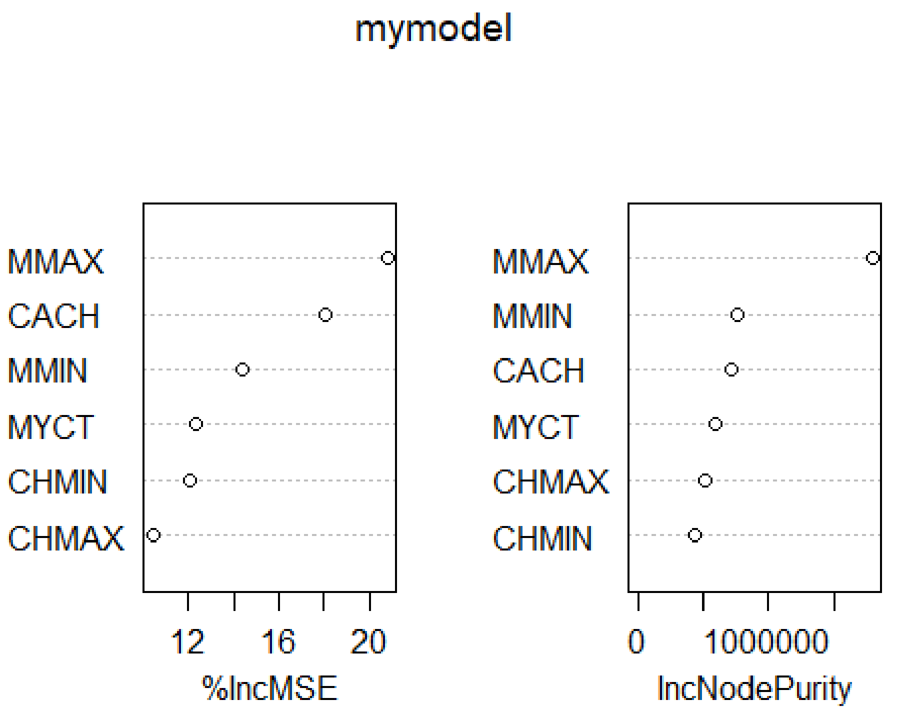
```
predtest = predict(mymodel, newdata = test)
restest = test$PRP - predtest
mse = mean(restest^2)

R2<- R2(predtest, test$PRP, form = "traditional")

rmse = sqrt(mse)
cat("MSE: ", mse," RMSE: ", rmse,  "R2: ", R2)

## MSE:  1352.706  RMSE:  36.77915 R2:  0.8649003
```

l. Develop a model to predict PRP using the Random Forest method.

```
mymodel = randomForest(PRP ~., data = train, importance = TRUE)
mymodel

##
## Call:
##  randomForest(formula = PRP ~ ., data = train, importance = TRUE)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 2
##
##           Mean of squared residuals: 3375.5
##                     % Var explained: 88.51
```

m. Provide variable importance plot and give your comments?

```
importance(mymodel)

##         %IncMSE IncNodePurity
## MYCT  12.29317      593191.2
## MMIN  14.38355      765801.3
## MMAX  20.80375     1795686.3
## CACH  18.07221      707943.6
## CHMIN 12.02622      430274.9
## CHMAX 10.46882      518347.5

varImpPlot(mymodel)
```



n. Compute the R2, mean square error and root mean square on training data. Give your comments on model accuracy.

```
predtrain = predict(mymodel, newdata = train)
restrain = train$PRP - predtrain
mset = mean(restrain^2)

R2t<- caret::R2(predtrain, train$PRP, form = "traditional")

rmset = sqrt(mse)
cat("MSE: ", mset," RMSE: ", rmset, "R2: ", R2t)

## MSE:  989.406  RMSE:  36.77915 R2:  0.9663127
```

o. Validate the model on test data? Compute mean square error and root mean square on test data. Give your comments on model generalizability.

```
predtest = predict(mymodel, newdata = test)
restest = test$PRP - predtest
mse = mean(restest^2)

R2<- R2(predtest, test$PRP, form = "traditional")

rmse = sqrt(mse)
cat("MSE: ", mse," RMSE: ", rmse,  "R2: ", R2)

## MSE:  923.7535  RMSE:  30.39331 R2:  0.9077413
```

p. Compare the Regression tree, bgging & random forest models and give your comments.

From Regression tree, bgging & random forest models we can easily compute that the model using **Random Forest** is best most model as comparision because the value of **RMSE** of Random Forest Model is **36** and **30** for training and testing data respectively.

q. Compare the Regression tree, bgging & random forest models with the linear regression model of assignment 2 and give your comments.

From Regression tree, bgging & random forest models we can easily compute that the model using **Random Forest** is best most model as comparision because the value of **RMSE** of Random Forest Model is **36** and **30** for training and testing data respectively.

Second Problem

SL No	Feature Name	Description
1	Age	Age
2	Sex	Sex
3	CP	Chest pain type
4	RestBP	Resting blood pressure
5	Cholesterol	Serum cholesterol in mg/dl
6	FBP	Fasting blood sugar > 120 mg/dl
7	RestECG	Resting electrocardiographic results
8	Max_HR	Maximum heart rate achieved
9	ExAngina	Exercise-induced angina
10	Oldpeak	ST depression induced by exercise relative to rest
11	Slope	The slope of the peak exercise ST segment
12	CA	Number of major vessels (0-3) colored by flourosopy
13	Thal	3 = normal; 6 = fixed defect; 7 = reversible defect

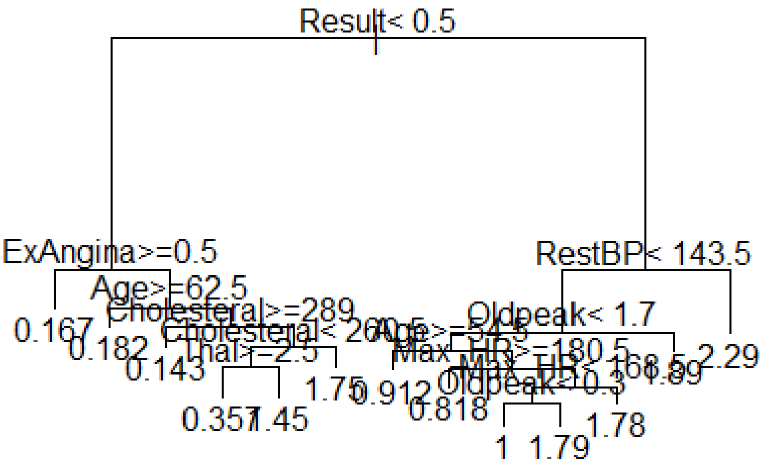
Load the Data

```
df<- readxl::read_excel("Heart_Disease_Data.xlsx")

# Head of Data
attach(df)

# Head of Data
head(df)

## # A tibble: 6 × 14
##     Age   Sex    CP RestBP Cholesteral   FBP RestECG Max_HR ExAngina Oldpe
ak
##   <dbl> <dbl> <dbl>  <dbl>       <dbl> <dbl>   <dbl>  <dbl>    <dbl>   <db
l>
## 1    63     1     3    145         233     1       0    150        0     2
.3
## 2    37     1     2    130         250     0       1    187        0     3
.5
## 3    41     0     1    130         204     0       0    172        0     1
.4
## 4    56     1     1    120         236     0       1    178        0     0
.8
## 5    57     0     0    120         354     0       1    163        1     0
.6
## 6    57     1     0    140         192     0       1    148        0     0
```

```
.4
## # … with 4 more variables: Slope <dbl>, CA <dbl>, Thal <dbl>, Result <dbl>

dim(df)

## [1] 303  14

names(df)

##  [1] "Age"          "Sex"          "CP"           "RestBP"       "Cholesteral"
##  [6] "FBP"          "RestECG"      "Max_HR"       "ExAngina"     "Oldpeak"
## [11] "Slope"        "CA"           "Thal"         "Result"
```

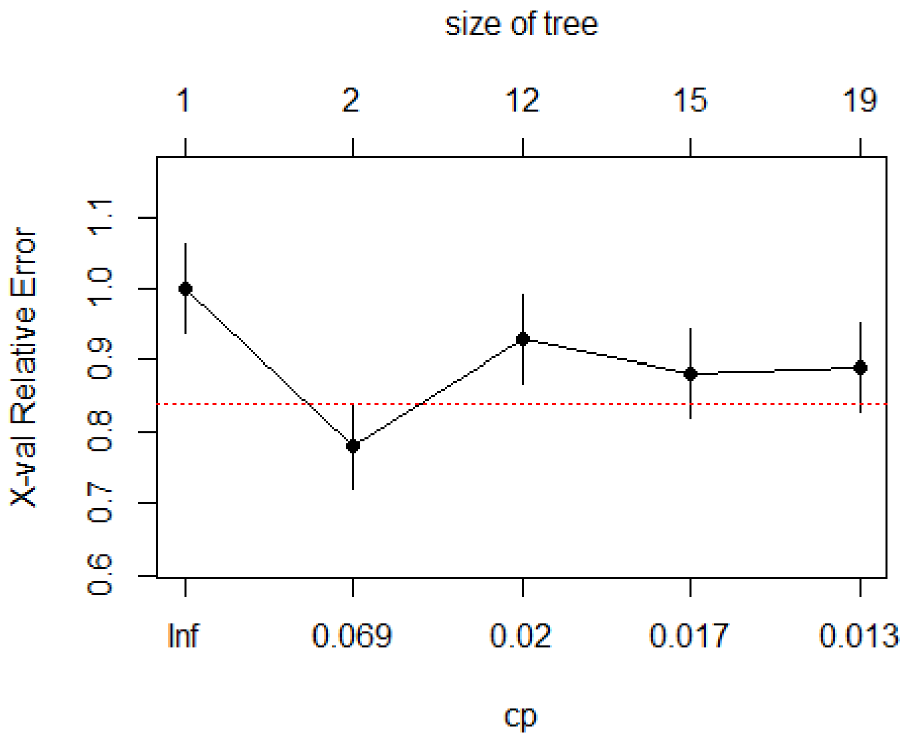
a. Split the data randomly into training (80%) and test (20%). Develop a classification tree model for Result

```
set.seed(1)
indexes = createDataPartition(CP, p = 0.80, list = F)
train = df[indexes, ]
test = df[-indexes, ]

train_x = train[, -14]
train_y = train[, 14]  # PRP

test_x = test[, -14]
test_y = test[, 14]  # PRP

dim(train_x)

## [1] 244  13

fit = rpart(CP ~ ., data = train)


par(xpd = NA) # otherwise on some devices the text is clipped
plot(fit)
text(fit, digits = 3)
```



b. Show the cp plot and give the optimum cp value

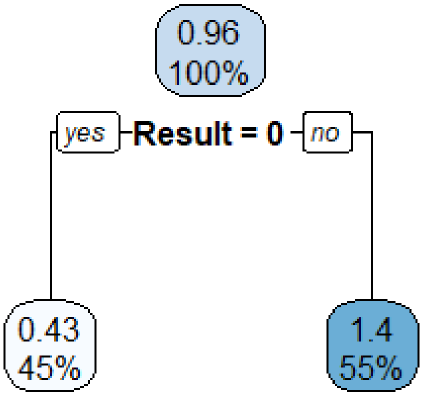
```
library(rpart.plot)
mymodel = rpart(CP ~. ,data = train, method = 'class', control = rpart.contro
l(minsplit = 2))

# Cross validation and identification of cp
plotcp(mymodel, pch = 19, col = "red")
```



Optimum $cp = 0.069$ Corresponding to minimum cross validation relative error

c. Display the best CART model obtained (rpart.plot) and give your interpretation

```
library(rpart.plot)
fit.pruned = prune(fit, cp = 0.069)

rpart.plot(fit.pruned)
```



d. Compute the actual versus predicted table, accuracy% and misclassification % on training data. Give your comments on model accuracy.

```
library("e1071")
model<- naiveBayes(CP ~. , train)

pred_y_tr = predict(model, train_x)


# Confusion Matrix
cmt <- table(train$CP, pred_y_tr)
# Model Evaluation
confusionMatrix(cmt)

## Confusion Matrix and Statistics
##
##    pred_y_tr
##      0  1  2  3
##   0 84 20 13  0
##   1  5 22  9  2
##   2 15 25 23  7
##   3  8  3  3  5
##
## Overall Statistics
##
##                 Accuracy : 0.5492
##                   95% CI : (0.4844, 0.6127)
##     No Information Rate : 0.459
##     P-Value [Acc > NIR] : 0.0029191
##
##                   Kappa : 0.3314
##
##  Mcnemar's Test P-Value : 0.0001818
##
## Statistics by Class:
##
##                      Class: 0 Class: 1 Class: 2 Class: 3
## Sensitivity            0.7500  0.31429  0.47917  0.35714
## Specificity            0.7500  0.90805  0.76020  0.93913
## Pos Pred Value         0.7179  0.57895  0.32857  0.26316
## Neg Pred Value         0.7795  0.76699  0.85632  0.96000
## Prevalence             0.4590  0.28689  0.19672  0.05738
## Detection Rate         0.3443  0.09016  0.09426  0.02049
## Detection Prevalence   0.4795  0.15574  0.28689  0.07787
## Balanced Accuracy      0.7500  0.61117  0.61969  0.64814
```

e. Validate the model on test data? Compute the actual versus predicted table, accuracy% and misclassification % on test data. Give your comments on model generalizability.

```
pred_y = predict(model, test_x)

## Warning in predict.naiveBayes(model, test_x): Type mismatch between traini
ng
## and new data for variable 'Result'. Did you use factors with numeric label
s for
## training, and numeric values for new data?

# Confusion Matrix
cm <- table(test$CP, pred_y)
# Model Evaluation
confusionMatrix(cm)

## Confusion Matrix and Statistics
##
##    pred_y
##      0  1  2  3
##   0 16  5  4  1
##   1  0  8  3  1
##   2  5  7  4  1
##   3  1  1  2  0
##
## Overall Statistics
##
##                Accuracy : 0.4746
##                  95% CI : (0.343, 0.6088)
##     No Information Rate : 0.3729
##     P-Value [Acc > NIR] : 0.07076
```

```
##
##                    Kappa : 0.2455
##
##  Mcnemar's Test P-Value : 0.31676
##
## Statistics by Class:
##
##                      Class: 0 Class: 1 Class: 2 Class: 3
## Sensitivity            0.7273   0.3810   0.3077  0.00000
## Specificity            0.7297   0.8947   0.7174  0.92857
## Pos Pred Value         0.6154   0.6667   0.2353  0.00000
## Neg Pred Value         0.8182   0.7234   0.7857  0.94545
## Prevalence             0.3729   0.3559   0.2203  0.05085
## Detection Rate         0.2712   0.1356   0.0678  0.00000
## Detection Prevalence   0.4407   0.2034   0.2881  0.06780
## Balanced Accuracy      0.7285   0.6378   0.5125  0.46429
```

f. Develop an optimum model to predict result using the Bagging method.

```
library(ipred)

#fit the bagged model
bag <- bagging(
  formula = CP ~ .,
  data = train,
  nbagg = 75,
  coob = TRUE,
  control = rpart.control(minsplit = 2, cp = 0.069)
)

#display fitted bagged model
bag

##
## Bagging regression trees with 75 bootstrap replications
##
## Call: bagging.data.frame(formula = CP ~ ., data = train, nbagg = 75,
##     coob = TRUE, control = rpart.control(minsplit = 2, cp = 0.069))
##
## Out-of-bag estimate of root mean squared error:  0.9108

help(pack = ipred)
```

g. Display variable importance plot and give your comments

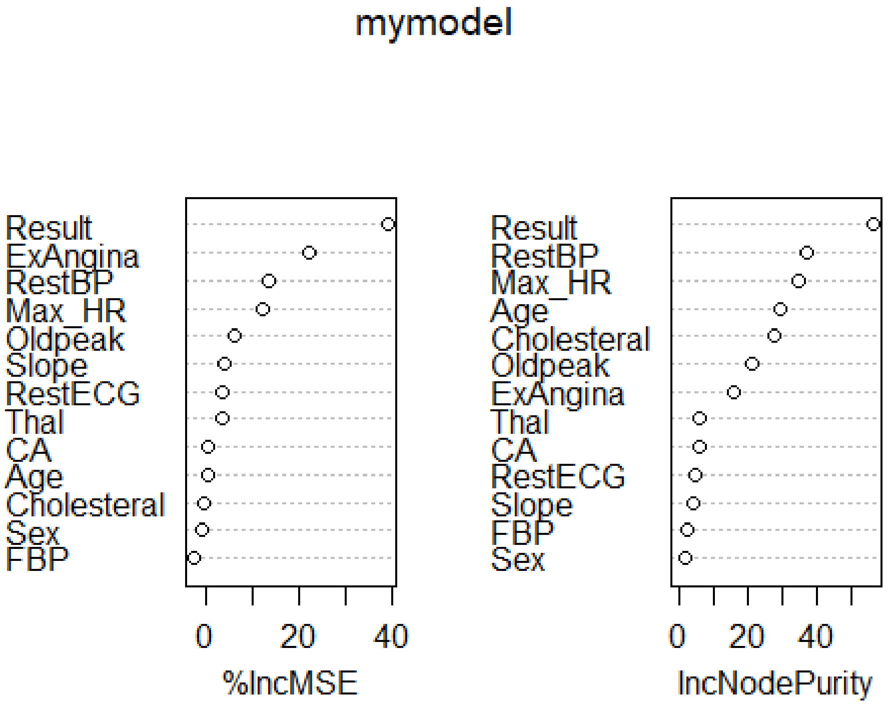
```
mymodel = randomForest(CP ~., data = train, mtry = 13, importance =  TRUE)

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

mymodel
```

```
##
## Call:
##  randomForest(formula = CP ~ ., data = train, mtry = 13, importance = TRUE
)
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 13
##
##           Mean of squared residuals: 0.8938037
##                     % Var explained: 16.97
```

```
importance(mymodel)
```

```
##                %IncMSE IncNodePurity
## Age          0.3049806     29.676163
## Sex         -0.9004688      2.227207
## RestBP      13.4855735     37.234712
## Cholesteral -0.5741186     27.518024
## FBP         -2.9522036      2.813637
## RestECG      3.3555424      4.741267
## Max_HR      11.9321115     34.820284
## ExAngina    22.0535058     15.995078
## Oldpeak      5.7362008     21.509038
## Slope        3.6464034      4.170251
## CA           0.3197481      6.105198
## Thal         3.1457704      6.191542
## Result      39.1690495     56.575561
```

```
varImpPlot(mymodel)
```



h. Compute the actual versus predicted table, accuracy% and misclassification % on training data. Give your comments on model accuracy.

```
pred_y_tr = predict(object = bag, newdata = train)

u <- union(pred_y_tr, train$CP)

t <- table(factor(pred_y_tr, u), factor(train$CP, u))

confusionMatrix(t)

## Confusion Matrix and Statistics
## Overall Statistics
##
##                Accuracy : 0
##                  95% CI : (0, 0.015)
##     No Information Rate : 0.4795
##     P-Value [Acc > NIR] : 1
##
##                   Kappa : 0
##
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
##
##                       Class: 1.80090803527369 Class: 1.43025804521044
## Sensitivity                               NA                      NA
## Specificity                 0.995902                 0.98361
## Pos Pred Value                    NA                      NA
## Neg Pred Value                    NA                      NA
## Prevalence                  0.000000                 0.00000
## Detection Rate              0.000000                 0.00000
## Detection Prevalence        0.004098                 0.01639
## Balanced Accuracy                 NA                      NA
##                      Class: 1.36483854045195 Class: 1.32299360144752
## Sensitivity                       NA                      NA
## Specificity                 0.991803                  0.8443
## Pos Pred Value                    NA                      NA
## Neg Pred Value                    NA                      NA
## Prevalence                  0.000000                  0.0000
## Detection Rate              0.000000                  0.0000
## Detection Prevalence        0.008197                  0.1557
## Balanced Accuracy                 NA                      NA
##                      Class: 1.79115320812881 Class: 1.82292157103211
## Sensitivity                       NA                      NA
## Specificity                 0.991803                  0.9877
## Pos Pred Value                    NA                      NA
## Neg Pred Value                    NA                      NA
## Prevalence                  0.000000                  0.0000
## Detection Rate              0.000000                  0.0000
## Detection Prevalence        0.008197                  0.0123
## Balanced Accuracy                 NA                      NA
##                      Class: 1.3384486948773 Class: 1.36202448123645
## Sensitivity                      NA                      NA
## Specificity                 0.97951                0.991803
## Pos Pred Value                   NA                      NA
## Neg Pred Value                   NA                      NA
## Prevalence                  0.00000                0.000000
## Detection Rate              0.00000                0.000000
## Detection Prevalence        0.02049                0.008197
## Balanced Accuracy                NA                      NA
##                      Class: 1.39141820314812 Class: 1.87550042594095
## Sensitivity                       NA                      NA
## Specificity                   0.9877                0.995902
## Pos Pred Value                    NA                      NA
## Neg Pred Value                    NA                      NA
## Prevalence                    0.0000                0.000000
## Detection Rate                0.0000                0.000000
## Detection Prevalence          0.0123                0.004098
## Balanced Accuracy                 NA                      NA
##                      Class: 1.44571313864022 Class: 1.29106772978122
## Sensitivity                       NA                      NA
## Specificity                 0.995902                0.995902
## Pos Pred Value                    NA                      NA
## Neg Pred Value                    NA                      NA
## Prevalence                  0.000000                0.000000
## Detection Rate              0.000000                0.000000
## Detection Prevalence                0.004098                0.004098
## Balanced Accuracy                         NA                      NA
##                      Class: 1.67908717903014 Class: 1.33673261429404
## Sensitivity                               NA                      NA
## Specificity                         0.991803                  0.8525
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                          0.000000                  0.0000
## Detection Rate                      0.000000                  0.0000
## Detection Prevalence                0.008197                  0.1475
## Balanced Accuracy                         NA                      NA
##                      Class: 1.28286596363144 Class: 1.34351723494384
## Sensitivity                               NA                      NA
## Specificity                         0.995902                0.995902
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                          0.000000                0.000000
## Detection Rate                      0.000000                0.000000
## Detection Prevalence                0.004098                0.004098
## Balanced Accuracy                         NA                      NA
##                      Class: 1.77651484928043 Class: 1.37797758857469
## Sensitivity                               NA                      NA
## Specificity                          0.97541                0.995902
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                           0.00000                0.000000
## Detection Rate                       0.00000                0.000000
## Detection Prevalence                 0.02459                0.004098
## Balanced Accuracy                         NA                      NA
##                      Class: 1.44399705805696 Class: 1.35218770772382
## Sensitivity                               NA                      NA
## Specificity                         0.991803                  0.9877
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                          0.000000                  0.0000
## Detection Rate                      0.000000                  0.0000
## Detection Prevalence                0.008197                  0.0123
## Balanced Accuracy                         NA                      NA
##                      Class: 1.25476003747353 Class: 1.2773287169347
## Sensitivity                               NA                     NA
## Specificity                          0.98361               0.995902
## Pos Pred Value                            NA                     NA
## Neg Pred Value                            NA                     NA
## Prevalence                           0.00000               0.000000
## Detection Rate                       0.00000               0.000000
## Detection Prevalence                 0.01639               0.004098
## Balanced Accuracy                         NA                     NA
##                      Class: 1.35109952760544 Class: 1.24102102462701
## Sensitivity                               NA                      NA
## Specificity                         0.995902                 0.97131
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                          0.000000                 0.00000
## Detection Rate                      0.000000                 0.00000
## Detection Prevalence                0.004098                 0.02869
## Balanced Accuracy                         NA                      NA
##                      Class: 1.3776791903016 Class: 1.31541130878592
## Sensitivity                              NA                      NA
## Specificity                        0.995902                0.995902
## Pos Pred Value                           NA                      NA
## Neg Pred Value                           NA                      NA
## Prevalence                         0.000000                0.000000
## Detection Rate                     0.000000                0.000000
## Detection Prevalence               0.004098                0.004098
## Balanced Accuracy                        NA                      NA
##                      Class: 1.90669651899413 Class: 1.76823598217803
## Sensitivity                               NA                      NA
## Specificity                         0.995902                0.995902
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                          0.000000                0.000000
## Detection Rate                      0.000000                0.000000
## Detection Prevalence                0.004098                0.004098
## Balanced Accuracy                         NA                      NA
##                      Class: 1.29428893117092 Class: 0.496614839875271
## Sensitivity                               NA                       NA
## Specificity                         0.995902                  0.91803
## Pos Pred Value                            NA                       NA
## Neg Pred Value                            NA                       NA
## Prevalence                          0.000000                  0.00000
## Detection Rate                      0.000000                  0.00000
## Detection Prevalence                0.004098                  0.08197
## Balanced Accuracy                         NA                       NA
##                      Class: 0.41185504696329 Class: 0.393494862347157
## Sensitivity                               NA                       NA
## Specificity                           0.9877                    0.877
## Pos Pred Value                            NA                       NA
## Neg Pred Value                            NA                       NA
## Prevalence                            0.0000                    0.000
## Detection Rate                        0.0000                    0.000
## Detection Prevalence                  0.0123                    0.123
## Balanced Accuracy                         NA                       NA
##                      Class: 0.50968662133415 Class: 0.406566643806035
## Sensitivity                               NA                       NA
## Specificity                          0.97541                  0.93443
## Pos Pred Value                            NA                       NA
## Neg Pred Value                            NA                       NA
## Prevalence                           0.00000                  0.00000
## Detection Rate                       0.00000                  0.00000
## Detection Prevalence                 0.02459                  0.06557
## Balanced Accuracy                         NA                       NA
##                      Class: 0.398783265504412 Class: 0.491326436718016
## Sensitivity                                NA                       NA
## Specificity                           0.96721                  0.94262
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                            0.00000                  0.00000
## Detection Rate                        0.00000                  0.00000
## Detection Prevalence                  0.03279                  0.05738
## Balanced Accuracy                          NA                       NA
##                      Class: 0.504398218176894 Class: 0.554274772535204
## Sensitivity                                NA                       NA
## Specificity                           0.98361                 0.995902
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                            0.00000                 0.000000
## Detection Rate                        0.00000                 0.000000
## Detection Prevalence                  0.01639                 0.004098
## Balanced Accuracy                          NA                       NA
##                      Class: 0.562300816981902 Class: 0.426746228467375
## Sensitivity                                NA                       NA
## Specificity                          0.995902                 0.995902
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                           0.000000                 0.000000
## Detection Rate                       0.000000                 0.000000
## Detection Prevalence                 0.004098                 0.004098
## Balanced Accuracy                          NA                       NA
##                      Class: 0.517508505784575 Class: 0.584822255862007
## Sensitivity                                NA                       NA
## Specificity                          0.995902                 0.995902
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                           0.000000                 0.000000
## Detection Rate                       0.000000                 0.000000
## Detection Prevalence                 0.004098                 0.004098
## Balanced Accuracy                          NA                       NA
##                      Class: 0.534095187873864 Class: 0.58940941843125
## Sensitivity                                NA                      NA
## Specificity                          0.995902                0.995902
## Pos Pred Value                             NA                      NA
## Neg Pred Value                             NA                      NA
## Prevalence                           0.000000                0.000000
## Detection Rate                       0.000000                0.000000
## Detection Prevalence                 0.004098                0.004098
## Balanced Accuracy                          NA                      NA
##                      Class: 0.524577802838234 Class: 0.545279841673133
## Sensitivity                                NA                       NA
## Specificity                          0.995902                 0.995902
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                           0.000000                 0.000000
## Detection Rate                       0.000000                 0.000000
## Detection Prevalence                 0.004098                 0.004098
## Balanced Accuracy                          NA                       NA
##                      Class: 0.521023406414985 Class: 3 Class: 2 Class: 1
## Sensitivity                                NA  0.00000   0.0000   0.0000
## Specificity                          0.995902  1.00000   1.0000   1.0000
## Pos Pred Value                             NA      NaN      NaN      NaN
## Neg Pred Value                             NA  0.92213   0.7131   0.8443
## Prevalence                           0.000000  0.07787   0.2869   0.1557
## Detection Rate                       0.000000  0.00000   0.0000   0.0000
## Detection Prevalence                 0.004098  0.00000   0.0000   0.0000
## Balanced Accuracy                          NA  0.50000   0.5000   0.5000
##                      Class: 0
## Sensitivity            0.0000
## Specificity            1.0000
## Pos Pred Value            NaN
## Neg Pred Value         0.5205
## Prevalence             0.4795
## Detection Rate         0.0000
## Detection Prevalence   0.0000
## Balanced Accuracy      0.5000
```

i. Validate the model on test data? Compute the actual versus predicted table, accuracy% and misclassification % on test data. Give your comments on model generalizability.

```
pred_y= predict(object = bag, newdata = test)

uu <- union(pred_y, test$CP)

tt <- table(factor(pred_y, uu), factor(test$CP, uu))

confusionMatrix(tt)

## Confusion Matrix and Statistics
##
##
## Overall Statistics
##
##                Accuracy : 0
##                  95% CI : (0, 0.0606)
##     No Information Rate : 0.4407
##     P-Value [Acc > NIR] : 1
##
##                   Kappa : 0
##
##  Mcnemar's Test P-Value : NA
##
## Statistics by Class:
```

```
##
##                      Class: 1.24102102462701 Class: 1.35218770772382
## Sensitivity                               NA                      NA
## Specificity                          0.98305                  0.9661
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                           0.00000                  0.0000
## Detection Rate                       0.00000                  0.0000
## Detection Prevalence                 0.01695                  0.0339
## Balanced Accuracy                         NA                      NA
##                      Class: 1.36655462103521 Class: 1.32299360144752
## Sensitivity                               NA                      NA
## Specificity                          0.98305                  0.8475
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                           0.00000                  0.0000
## Detection Rate                       0.00000                  0.0000
## Detection Prevalence                 0.01695                  0.1525
## Balanced Accuracy                         NA                      NA
##                      Class: 1.77651484928043 Class: 1.81604374297782
## Sensitivity                               NA                      NA
## Specificity                          0.91525                 0.98305
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                           0.00000                 0.00000
## Detection Rate                       0.00000                 0.00000
## Detection Prevalence                 0.08475                 0.01695
## Balanced Accuracy                         NA                      NA
##                      Class: 1.31917365593913 Class: 1.3384486948773
## Sensitivity                               NA                     NA
## Specificity                          0.98305                0.98305
## Pos Pred Value                            NA                     NA
## Neg Pred Value                            NA                     NA
## Prevalence                           0.00000                0.00000
## Detection Rate                       0.00000                0.00000
## Detection Prevalence                 0.01695                0.01695
## Balanced Accuracy                         NA                     NA
##                      Class: 1.33673261429404 Class: 1.37626150799143
## Sensitivity                               NA                      NA
## Specificity                           0.8814                 0.98305
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                            0.0000                 0.00000
## Detection Rate                        0.0000                 0.00000
## Detection Prevalence                  0.1186                 0.01695
## Balanced Accuracy                         NA                      NA
##                      Class: 1.44399705805696 Class: 1.76823598217803
## Sensitivity                               NA                      NA
## Specificity                          0.98305                 0.98305
## Pos Pred Value                            NA                      NA
## Neg Pred Value                            NA                      NA
## Prevalence                           0.00000                 0.00000
## Detection Rate                       0.00000                 0.00000
## Detection Prevalence                 0.01695                 0.01695
## Balanced Accuracy                         NA                      NA
##                      Class: 1.87550042594095 Class: 0.393494862347157
## Sensitivity                               NA                       NA
## Specificity                          0.98305                   0.8475
## Pos Pred Value                            NA                       NA
## Neg Pred Value                            NA                       NA
## Prevalence                           0.00000                   0.0000
## Detection Rate                       0.00000                   0.0000
## Detection Prevalence                 0.01695                   0.1525
## Balanced Accuracy                         NA                       NA
##                      Class: 0.496614839875271 Class: 0.50968662133415
## Sensitivity                                NA                      NA
## Specificity                            0.9322                  0.9322
## Pos Pred Value                             NA                      NA
## Neg Pred Value                             NA                      NA
## Prevalence                             0.0000                  0.0000
## Detection Rate                         0.0000                  0.0000
## Detection Prevalence                   0.0678                  0.0678
## Balanced Accuracy                          NA                      NA
##                      Class: 0.406566643806035 Class: 0.41185504696329
## Sensitivity                                NA                      NA
## Specificity                           0.98305                 0.94915
## Pos Pred Value                             NA                      NA
## Neg Pred Value                             NA                      NA
## Prevalence                            0.00000                 0.00000
## Detection Rate                        0.00000                 0.00000
## Detection Prevalence                  0.01695                 0.05085
## Balanced Accuracy                          NA                      NA
##                      Class: 0.54019401397269 Class: 0.512220102627319
## Sensitivity                               NA                       NA
## Specificity                          0.98305                  0.98305
## Pos Pred Value                            NA                       NA
## Neg Pred Value                            NA                       NA
## Prevalence                           0.00000                  0.00000
## Detection Rate                       0.00000                  0.00000
## Detection Prevalence                 0.01695                  0.01695
## Balanced Accuracy                         NA                       NA
##                      Class: 0.521023406414985 Class: 0.398783265504412
## Sensitivity                                NA                       NA
## Specificity                           0.98305                   0.9661
## Pos Pred Value                             NA                       NA
## Neg Pred Value                             NA                       NA
## Prevalence                            0.00000                   0.0000
## Detection Rate                        0.00000                   0.0000
## Detection Prevalence                  0.01695                   0.0339
## Balanced Accuracy                          NA                       NA
##                      Class: 0.504398218176894 Class: 0 Class: 1 Class: 3
## Sensitivity                                NA   0.0000   0.0000   0.0000
## Specificity                           0.98305   1.0000   1.0000   1.0000
## Pos Pred Value                             NA      NaN      NaN      NaN
## Neg Pred Value                             NA   0.5593   0.7966   0.9322
## Prevalence                            0.00000   0.4407   0.2034   0.0678
## Detection Rate                        0.00000   0.0000   0.0000   0.0000
## Detection Prevalence                  0.01695   0.0000   0.0000   0.0000
## Balanced Accuracy                          NA   0.5000   0.5000   0.5000
##                      Class: 2
## Sensitivity            0.0000
## Specificity            1.0000
## Pos Pred Value            NaN
## Neg Pred Value         0.7119
## Prevalence             0.2881
## Detection Rate         0.0000
## Detection Prevalence   0.0000
## Balanced Accuracy      0.5000
```

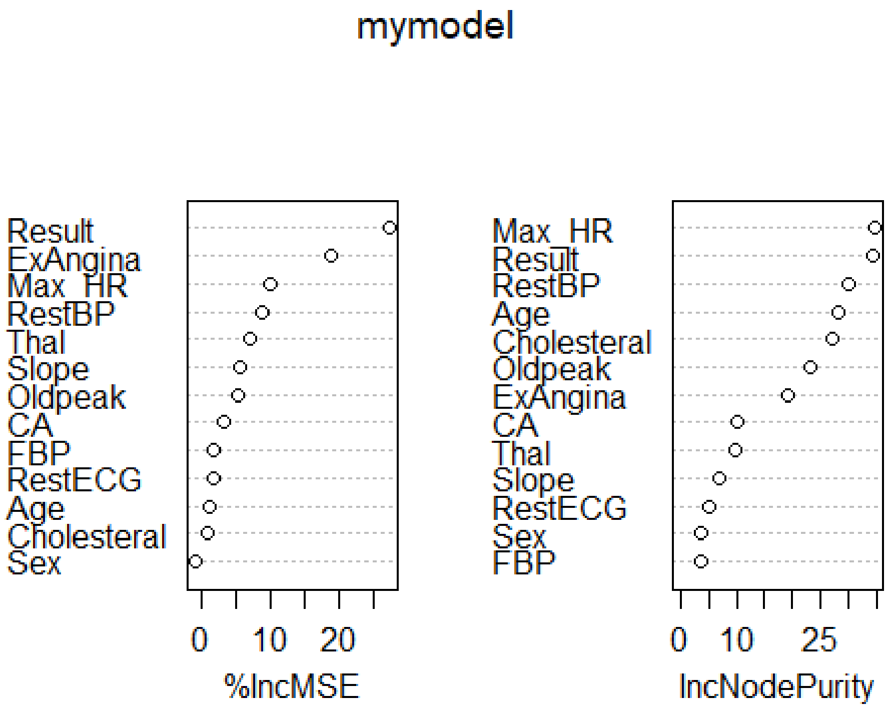
j. Develop a model to predict result using the Random Forest method.

```
mymodel = randomForest(CP ~., data = train, importance = TRUE)
mymodel

## 
## Call:
##  randomForest(formula = CP ~ ., data = train, importance = TRUE) 
##                Type of random forest: regression
##                      Number of trees: 500
## No. of variables tried at each split: 4
## 
##           Mean of squared residuals: 0.8181326
##                     % Var explained: 24
```

k. Display variable importance plot and give your comments

```
importance(mymodel)

##                %IncMSE IncNodePurity
## Age          1.1834613     28.170212
## Sex         -0.8939923      3.599703
## RestBP       8.7912906     30.006374
## Cholesteral  0.9630746     26.865687
## FBP          1.9368725      3.592575
## RestECG      1.8069184      5.138652
## Max_HR      10.1354431     34.670196
## ExAngina    18.7043267     19.127504
## Oldpeak      5.2991589     23.032267
## Slope        5.5418174      7.117615
## CA           3.2771599     10.103610
## Thal         7.1393276      9.820835
## Result      27.3293142     34.025461
```

```
varImpPlot(mymodel)
```



l. Compute the actual versus predicted table, accuracy % and misclassification % on training data. Give your comments on model accuracy.

```
pred_y_tr = predict(mymodel, train)

u <- union(pred_y_tr, train$CP)

t <- table(factor(pred_y_tr, u), factor(train$CP, u))

confusionMatrix(t)
```

m. Validate the model on test data? Compute the actual versus predicted table, accuracy % and misclassification % on test data. Give your comments on model generalizability.

```
pred_y= predict(object = mymodel, newdata = test)

uu <- union(pred_y, test$CP)

tt <- table(factor(pred_y, uu), factor(test$CP, uu))

confusionMatrix(tt)
```

n. Compare the classification tree, bagging & random forest models and give your comments.

From Regression tree, bgging & random forest models we can easily compute that the model using Random Forest is best most model as comparision because the value of specificity of Random Forest Model is high training and testing data respectively.

o. Compare the classification tree, bgging & random forest models with the logistic regression model of assignment 2 and give your comments.