

DTWineQualityC50.R

ai

Mon Jun 5 18:32:02 2017

```
# Reference for data source (  
# @misc{Lichman:2013 ,  
# author = "M. Lichman",  
# year = "2013",  
# title = "{UCI} Machine Learning Repository",  
# url = "http://archive.ics.uci.edu/ml",  
# institution = "University of California, Irvine, School of Information and Computer Sciences" })  
  
# Decision Trees  
# Source of Data Set:- UCI Repository - Wine Quality Data(https://archive.ics.uci.edu/ml/datasets/winequality)  
  
# Exploring and preparing the data  
# Step 2: Exploring and preparing the data  
# Read the csv file into a data frame titled WineData.  
WineData <- read.table("winequality-red.csv", sep=";", header=TRUE)  
  
head(WineData)  
  
##      fixed.acidity volatile.acidity citric.acid residual.sugar chlorides  
## 1           7.4           0.70           0.00           1.9       0.076  
## 2           7.8           0.88           0.00           2.6       0.098  
## 3           7.8           0.76           0.04           2.3       0.092  
## 4          11.2           0.28           0.56           1.9       0.075  
## 5           7.4           0.70           0.00           1.9       0.076  
## 6           7.4           0.66           0.00           1.8       0.075  
##      free.sulfur.dioxide total.sulfur.dioxide density    pH sulphates alcohol  
## 1              11              34 0.9978 3.51      0.56    9.4  
## 2              25              67 0.9968 3.20      0.68    9.8  
## 3              15              54 0.9970 3.26      0.65    9.8  
## 4              17              60 0.9980 3.16      0.58    9.8  
## 5              11              34 0.9978 3.51      0.56    9.4  
## 6              13              40 0.9978 3.51      0.56    9.4  
##      quality  
## 1          5  
## 2          5  
## 3          5  
## 4          6  
## 5          5  
## 6          5  
  
table(WineData$quality)  
  
##  
##      3      4      5      6      7      8  
##    10    53   681   638   199   18  
  
# Identify missing values using graphical view. See the Rplot.pdf and red colour stripes indicate the missing values  
library(Amelia)
```

```
## Loading required package: Rcpp

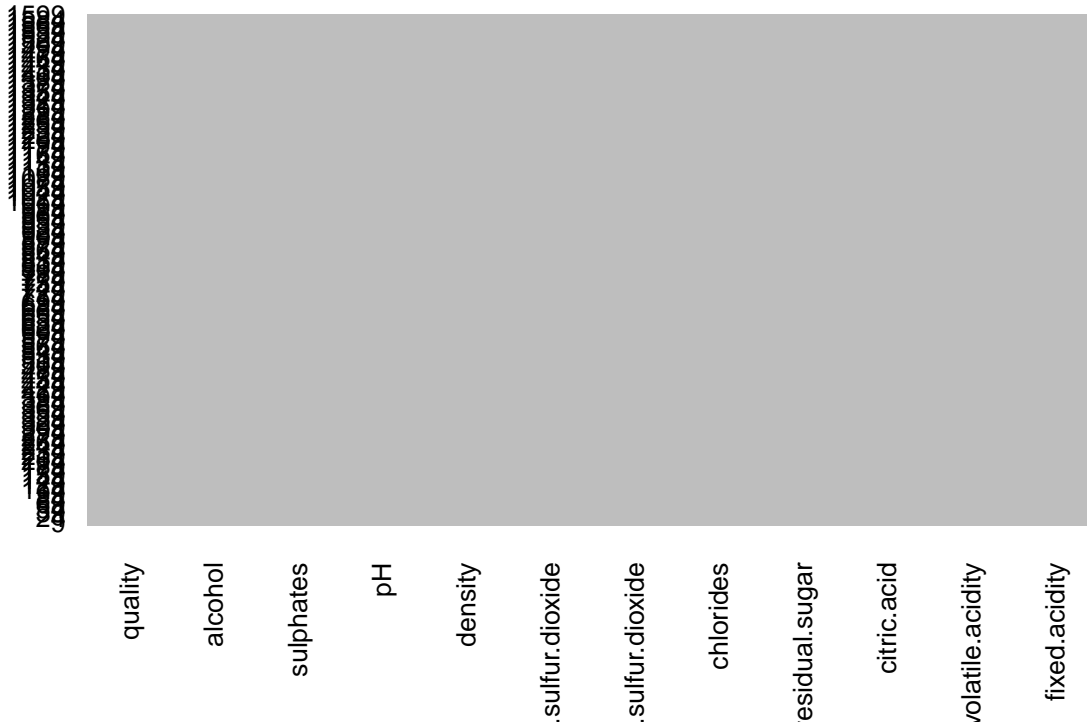
## ##
## ## Amelia II: Multiple Imputation
## ## (Version 1.7.4, built: 2015-12-05)
## ## Copyright (C) 2005-2017 James Honaker, Gary King and Matthew Blackwell
## ## Refer to http://gking.harvard.edu/amelia/ for more information
## ##

missmap(WineData, main="Missing Data - Red Wine Quality", col=c("red","grey"), legend=FALSE)

# Data Visualization
# plot histogram of fixed acidity

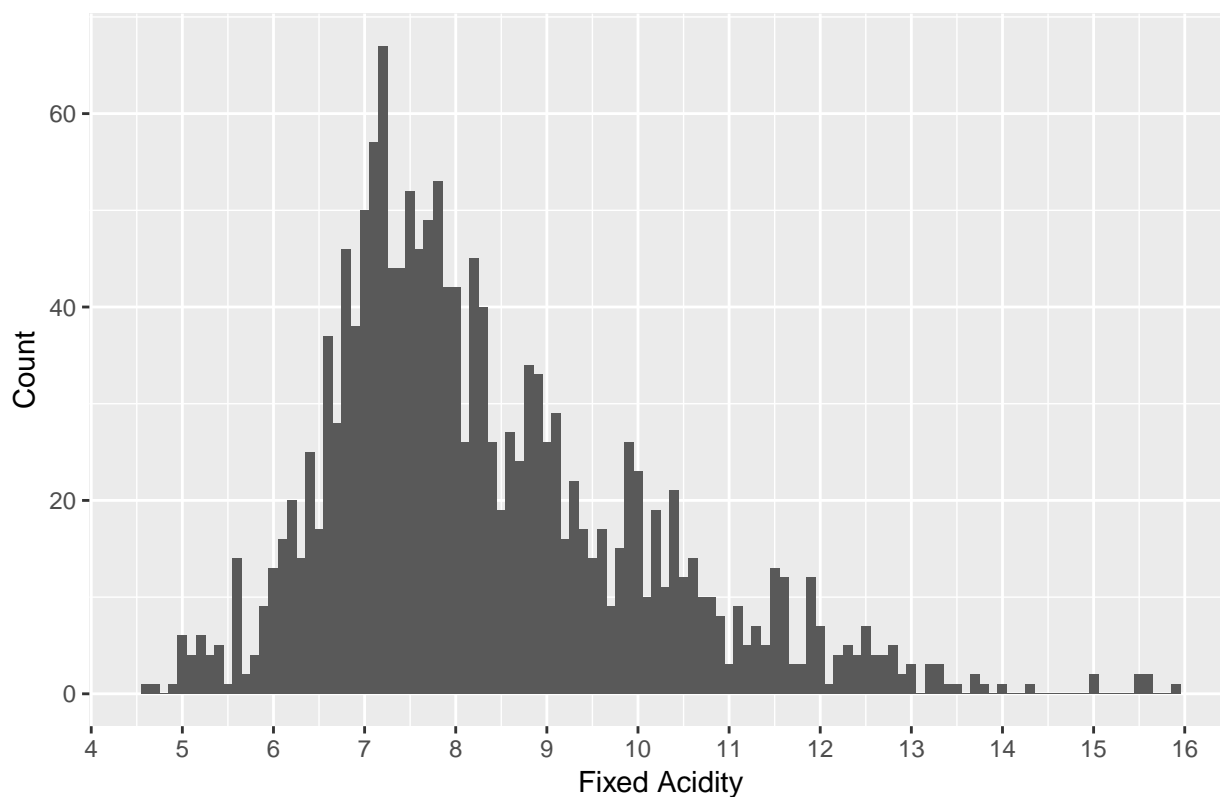
library(ggplot2)
```

Missing Data – Red Wine Quality



```
ggplot(WineData, aes(x = fixed.acidity)) +
  geom_histogram(binwidth = 0.1) +
  scale_x_continuous(breaks = seq(4, 16, by = 1)) +
  ggtitle("Fixed Acidity distribution") +
  xlab("Fixed Acidity") +
  ylab("Count")
```

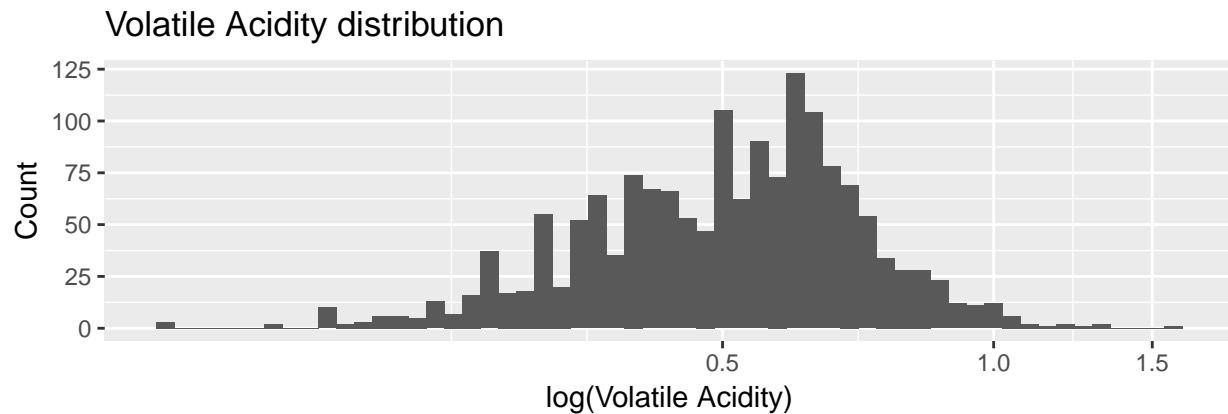
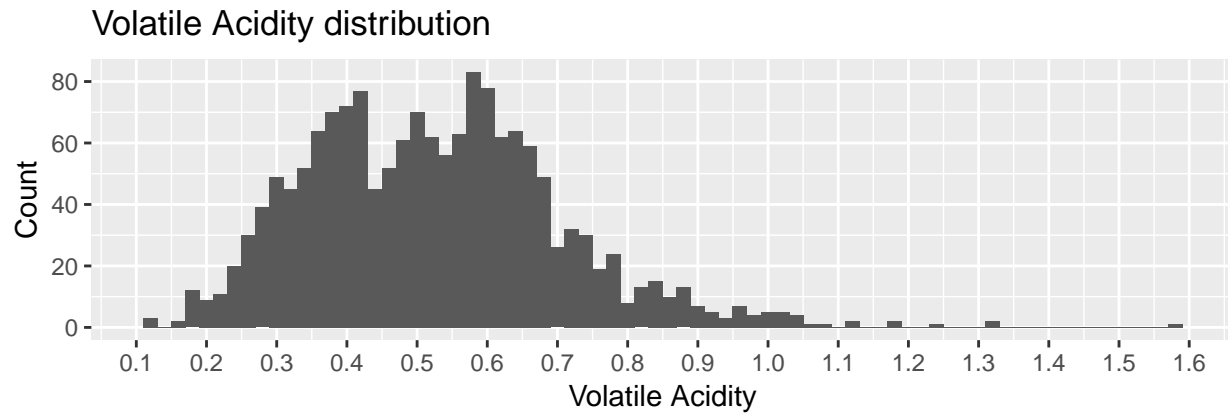
Fixed Acidity distribution



```
# plot histogram of Volatile Acidity
plot1 <- ggplot(WineData, aes(x = volatile.acidity)) +
  geom_histogram(binwidth = 0.02) +
  scale_x_continuous(breaks = seq(0, 1.6, by = 0.1)) +
  ggtitle("Volatile Acidity distribution") +
  xlab("Volatile Acidity") +
  ylab("Count")

plot2 <- ggplot(WineData, aes(x = volatile.acidity)) +
  geom_histogram(binwidth = 0.02) +
  scale_x_log10(breaks = seq(0, 1.6, by = 0.5)) +
  ggtitle("Volatile Acidity distribution") +
  xlab("log(Volatile Acidity)") +
  ylab("Count")

# gridExtra: Miscellaneous Functions for "Grid" Graphics.
library(gridExtra)
grid.arrange(plot1, plot2)
```



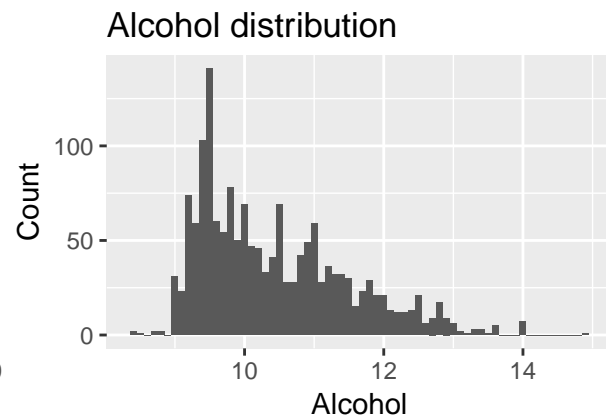
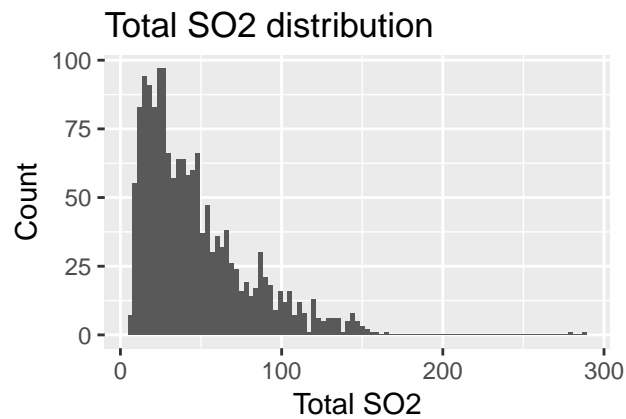
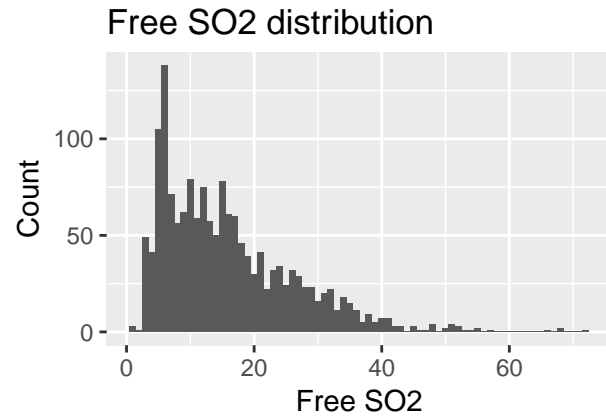
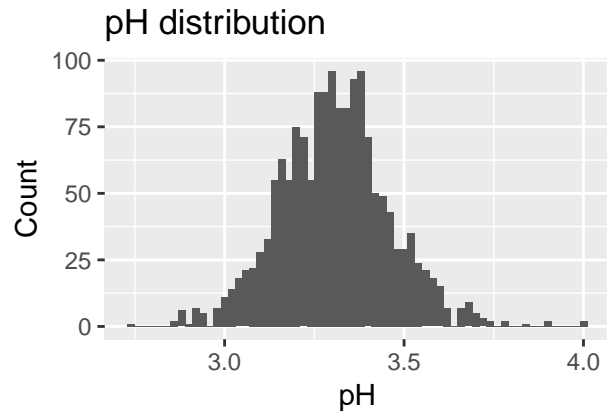
```
# plot histogram of pH
p1 <- ggplot(WineData, aes(x = pH)) +
  geom_histogram(binwidth = 0.02) +
  ggtitle("pH distribution") +
  xlab("pH") +
  ylab("Count")

# plot histogram of Free SO2
p2 <- ggplot(WineData, aes(x = free.sulfur.dioxide)) +
  geom_histogram(binwidth = 1) +
  ggtitle("Free SO2 distribution") +
  xlab("Free SO2") +
  ylab("Count")

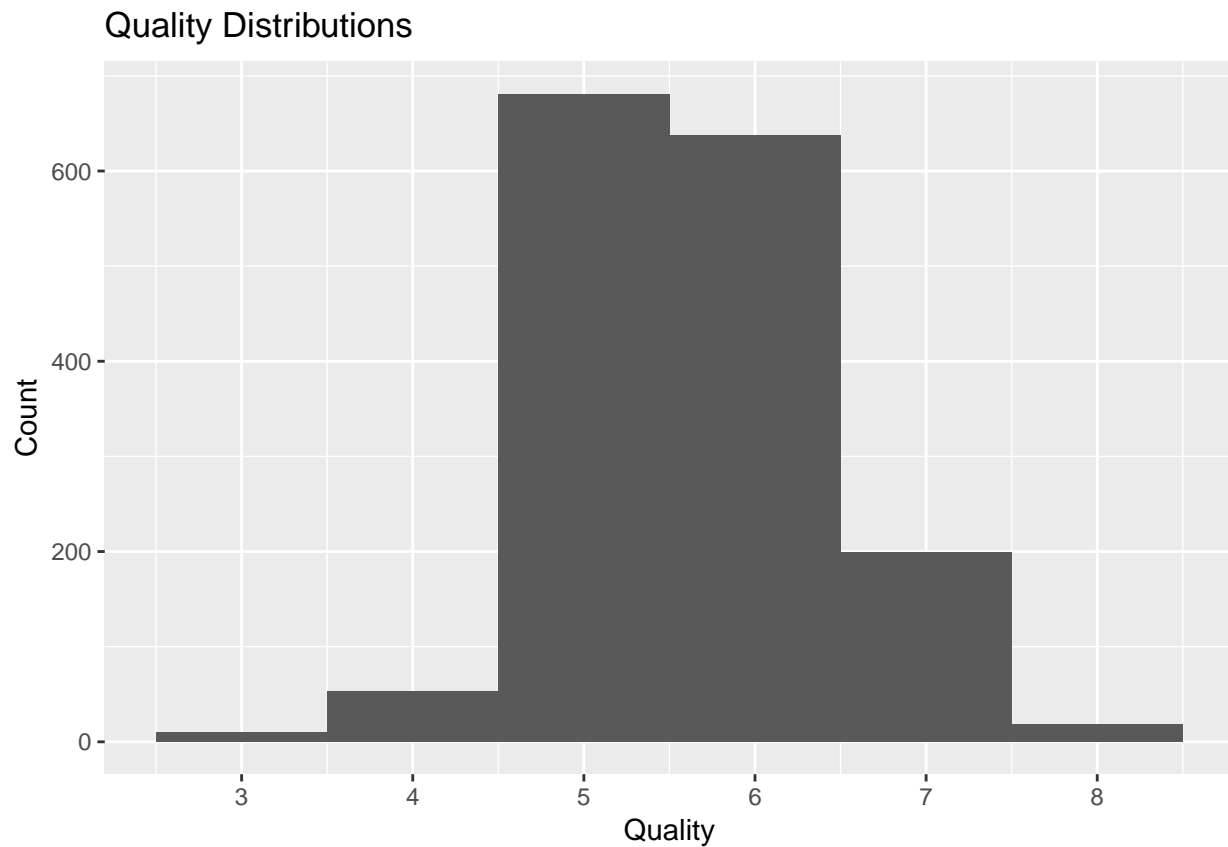
# plot histogram of Total SO2
p3 <- ggplot(WineData, aes(x = total.sulfur.dioxide)) +
  geom_histogram(binwidth = 3) +
  ggtitle("Total SO2 distribution") +
  xlab("Total SO2") +
  ylab("Count")

# plot histogram of Alcohol
p4 <- ggplot(WineData, aes(x = alcohol)) +
  geom_histogram(binwidth = 0.1) +
  ggtitle("Alcohol distribution") +
  xlab("Alcohol") +
  ylab("Count")
```

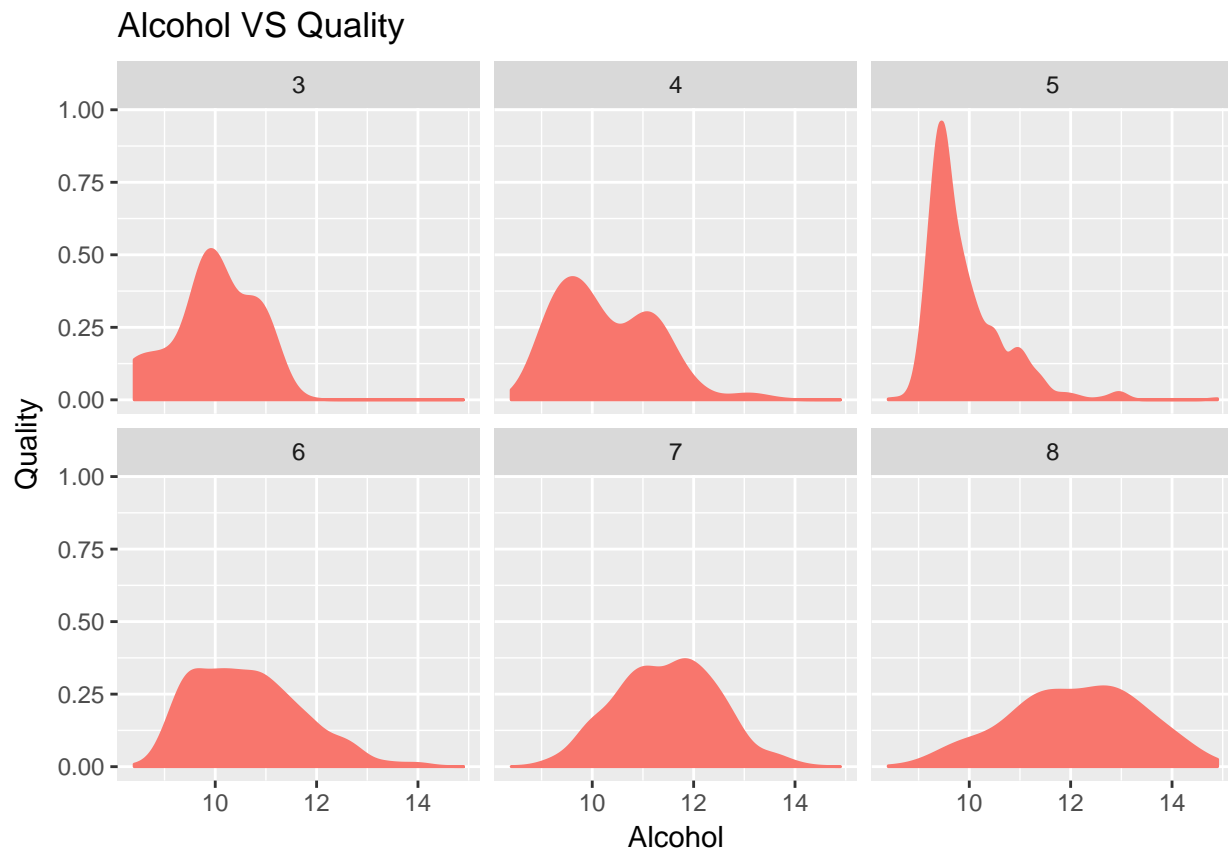
```
grid.arrange(p1, p2, p3, p4, ncol = 2)
```



```
# plot histogram of Quality
ggplot(WineData, aes(x = quality)) +
  geom_histogram(binwidth = 1) +
  scale_x_continuous(breaks = seq(3, 8, by = 1)) +
  ggtitle("Quality Distributions") +
  xlab("Quality") +
  ylab("Count")
```

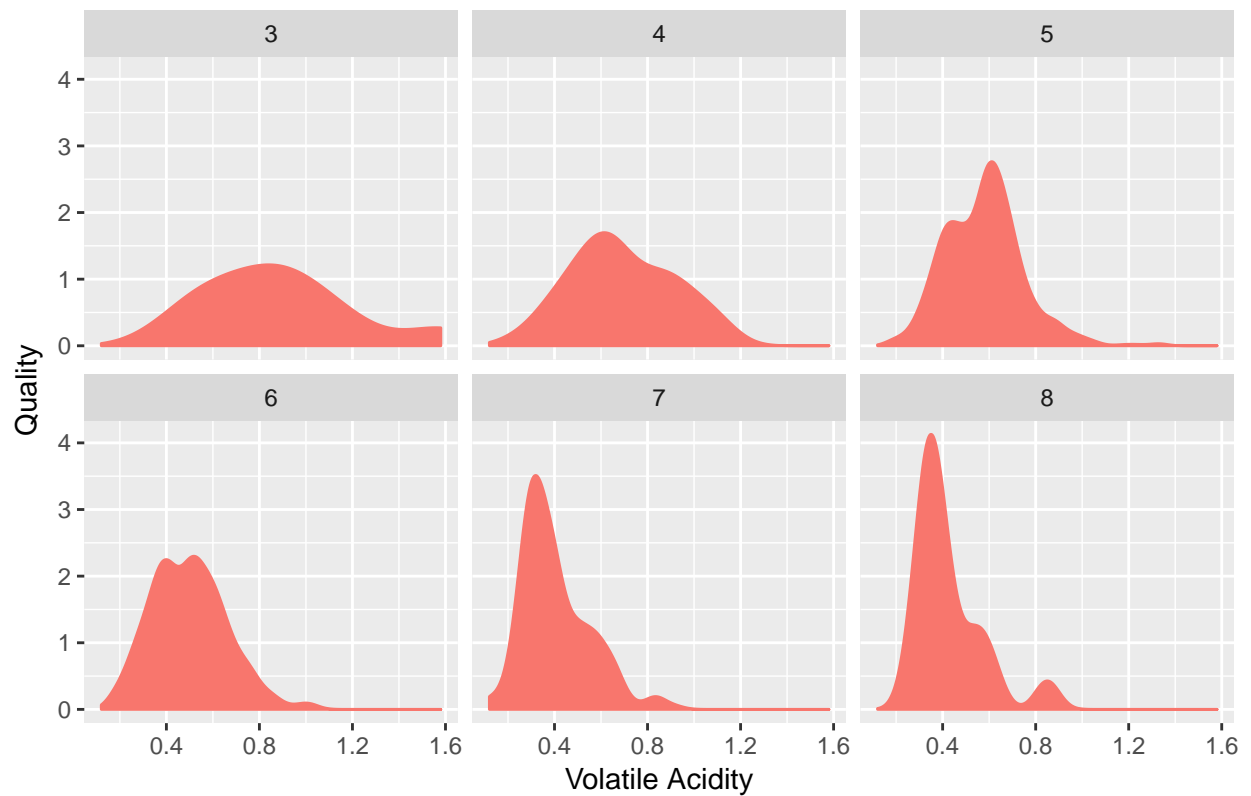


```
# Positive correlation of alcohol and quality  
ggplot(WineData, aes(x = alcohol)) +  
  geom_density(aes(fill = "red", color = "red")) +  
  facet_wrap(~quality) +  
  theme(legend.position = "none") +  
  ggtitle("Alcohol VS Quality") +  
  xlab("Alcohol") +  
  ylab("Quality")
```



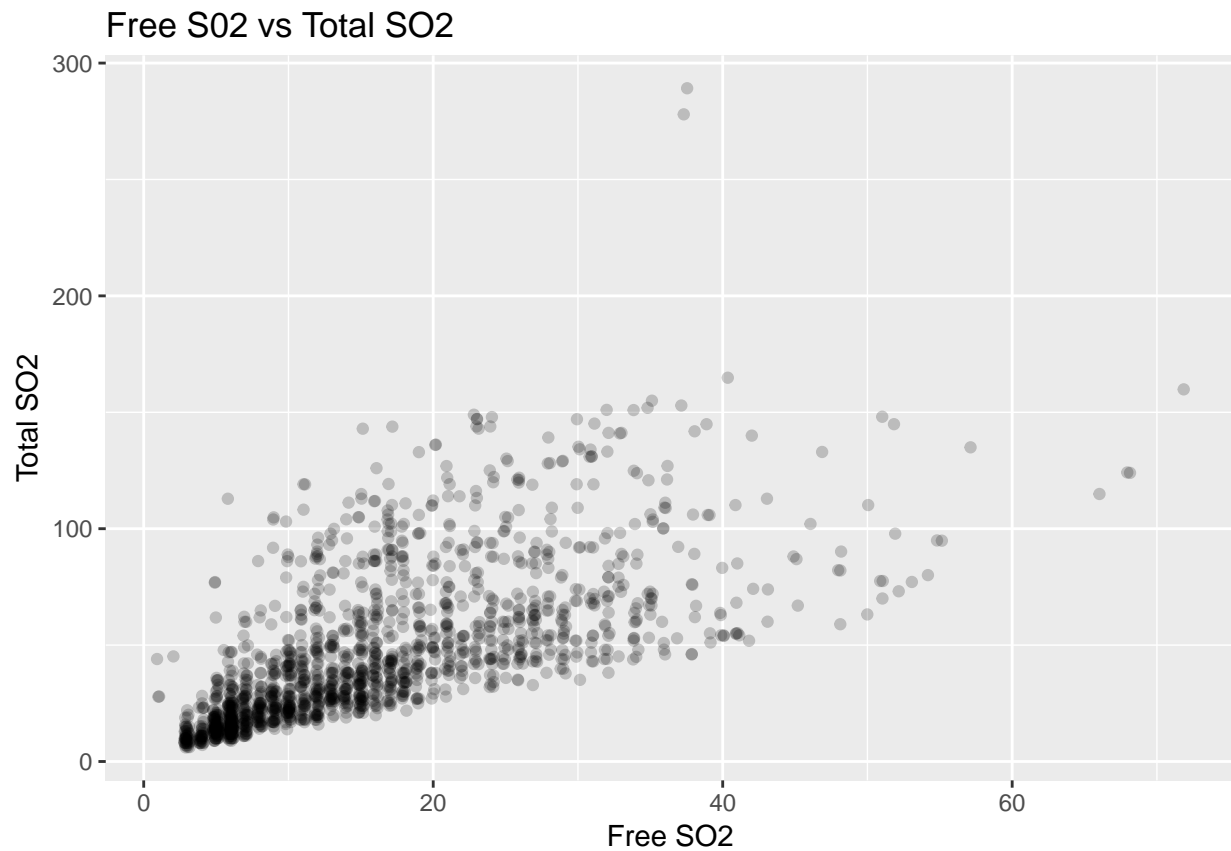
```
# Negative correlation of volatile acidity and quality
ggplot(WineData, aes(x = volatile.acidity)) +
  geom_density(aes(fill = "red", color = "red")) +
  facet_wrap(~quality) +
  theme(legend.position = "none") +
  ggtitle("Volatile Acidity VS Quality") +
  xlab("Volatile Acidity") +
  ylab("Quality")
```

Volatile Acidity VS Quality



Positive correlation of Free SO₂ and Total SO₂

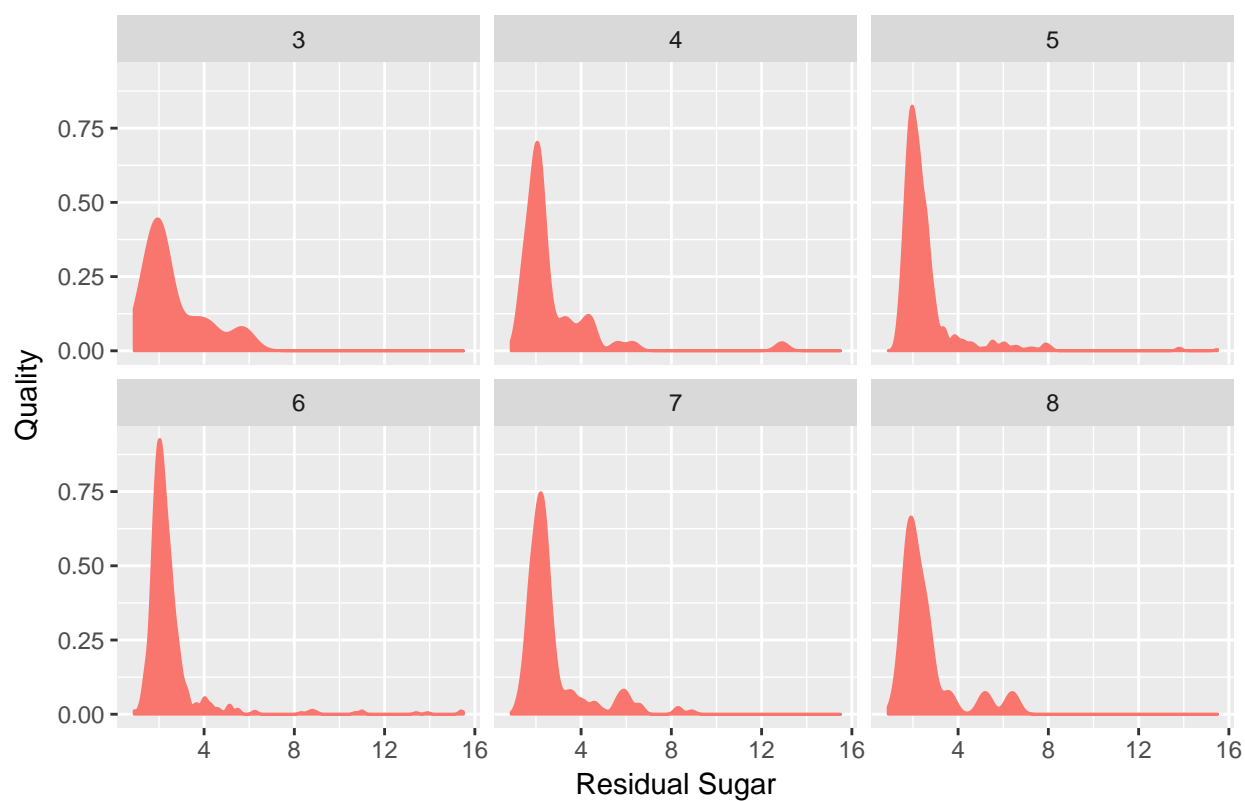
```
ggplot(WineData, aes(x = free.sulfur.dioxide, y = total.sulfur.dioxide)) +
  geom_jitter(alpha = 1/5) +
  ggtitle("Free S02 vs Total S02") +
  xlab("Free S02") +
  ylab("Total S02")
```

```
# residual sugar and quality relationship

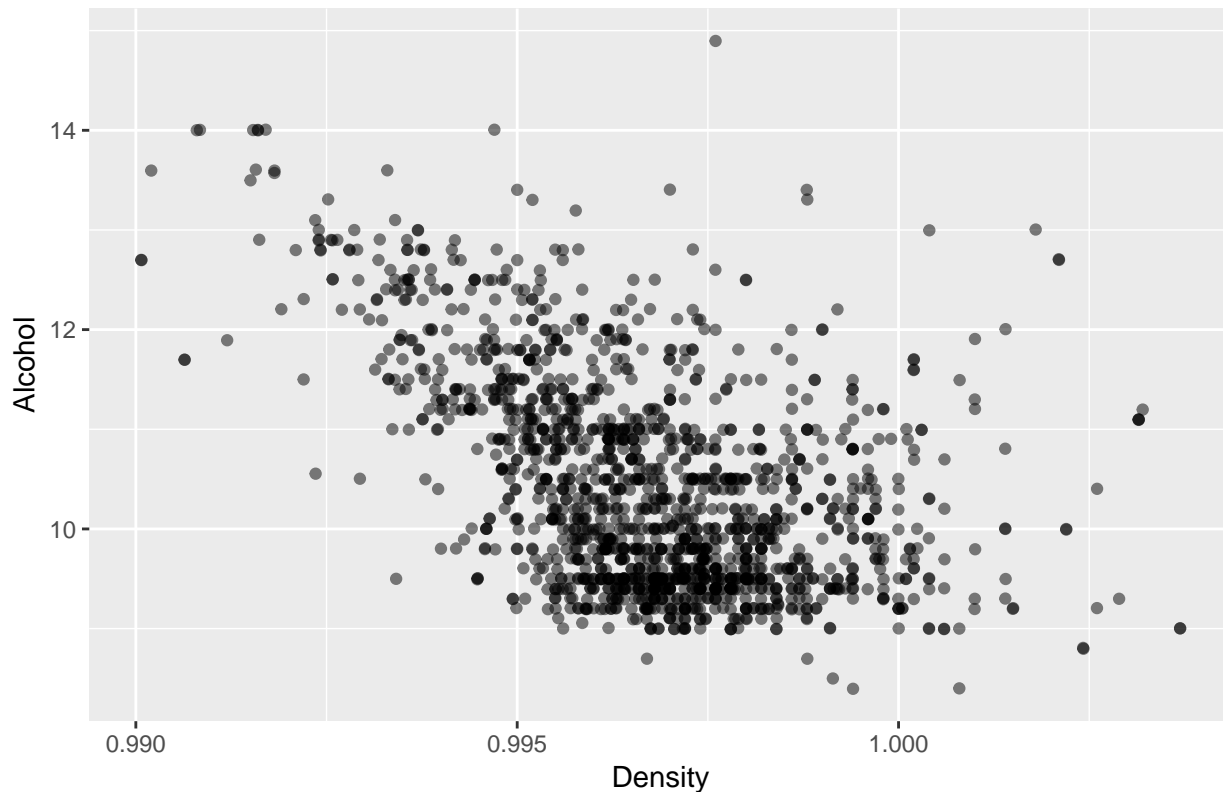
ggplot(WineData, aes(x = residual.sugar)) +
  geom_density(aes(fill = "red", color = "red")) +
  facet_wrap(~quality) +
  theme(legend.position = "none") +
  ggtitle("Residual Sugar VS Quality") +
  xlab("Residual Sugar") +
  ylab("Quality")
```

Residual Sugar VS Quality



```
# Density and Alcohol
ggplot(WineData, aes(x = density, y = alcohol)) +
  geom_jitter(alpha = 1/2) +
  ggtitle("Density VS Alcohol") +
  xlab("Density") +
  ylab("Alcohol")
```

Density VS Alcohol



```
# Creating a categorical variable for wine quality
# WineData$quality <- ifelse(WineData$quality == 3, "Lev_Three", ifelse(WineData$quality == 4, "Lev_Four", "Lev_Five"))
# WineData$quality <- as.factor(WineData$quality)
# str(WineData)

WineData$quality <- ifelse(WineData$quality < 5, 'bad', ifelse(WineData$quality > 6, 'good', 'normal'))
WineData$quality <- as.factor(WineData$quality)
str(WineData$quality)

## Factor w/ 3 levels "bad","good","normal": 3 3 3 3 3 3 3 2 2 3 ...

# Data preparation - creating random training and test datasets
# Create random sample
# Divide the data into a training set and a test set randomly with ratio 80:20

set.seed(123)
train_sample <- sample(nrow(WineData), 0.8 * nrow(WineData))
WineData_train <- WineData[train_sample, ]
WineData_test <- WineData[-train_sample, ]

# Check whether data set fairly even split
prop.table(table(WineData_train$quality))

##
##          bad          good          normal
## 0.03909304 0.13995309 0.82095387

prop.table(table(WineData_test$quality))
```

```

##
##      bad      good    normal
## 0.040625 0.118750 0.840625
# Train model

# # C5.0
# # # Training a model on the data
# # # The C5.0 package can be installed via the install.packages("C50") and
# # # loaded with the library(C50) command.
library(C50)

WineData_model <- C5.0(WineData_train[-12], WineData_train$quality)
WineData_model

##
## Call:
## C5.0.default(x = WineData_train[-12], y = WineData_train$quality)
##
## Classification Tree
## Number of samples: 1279
## Number of predictors: 11
##
## Tree size: 62
##
## Non-standard options: attempt to group attributes
# See the tree's decisions
summary(WineData_model)

##
## Call:
## C5.0.default(x = WineData_train[-12], y = WineData_train$quality)
##
##
## C5.0 [Release 2.07 GPL Edition]      Mon Jun  5 18:32:06 2017
## -----
##
## Class specified by attribute `outcome'
##
## Read 1279 cases (12 attributes) from undefined.data
##
## Decision tree:
##
## alcohol <= 10.4:
## :...fixed.acidity > 11.5:
## :   :...pH > 3.24: bad (2)
## :   :   pH <= 3.24:
## :   :   :...volatile.acidity > 0.32: normal (34/3)
## :   :   :   volatile.acidity <= 0.32:
## :   :   :   :...residual.sugar <= 2.4: good (8/2)
## :   :   :   :   residual.sugar > 2.4: normal (2)
## :   fixed.acidity <= 11.5:
## :   :...volatile.acidity <= 0.75: normal (597/29)

```

```

## :      volatile.acidity > 0.75:
## :      :...pH <= 3.28: normal (33)
## :      pH > 3.28:
## :      :...residual.sugar > 2.25: normal (23/1)
## :      residual.sugar <= 2.25:
## :      :...sulphates > 0.63: normal (4/1)
## :      sulphates <= 0.63:
## :      :...fixed.acidity > 7.4: bad (6)
## :      fixed.acidity <= 7.4:
## :      :...fixed.acidity <= 6.3: bad (2)
## :      fixed.acidity > 6.3:
## :      :...free.sulfur.dioxide <= 11: normal (4)
## :      free.sulfur.dioxide > 11: bad (4/1)
## alcohol > 10.4:
## :...sulphates > 0.67:
## :      :...alcohol > 11.5:
## :      :      :...fixed.acidity > 12.2: normal (5)
## :      :      fixed.acidity <= 12.2:
## :      :      :...free.sulfur.dioxide <= 18: good (60/9)
## :      :      free.sulfur.dioxide > 18:
## :      :      :...residual.sugar > 4.6: good (3)
## :      :      residual.sugar <= 4.6:
## :      :      :...free.sulfur.dioxide <= 27:
## :      :      :...total.sulfur.dioxide > 50: normal (9)
## :      :      :      total.sulfur.dioxide <= 50:
## :      :      :      :...chlorides <= 0.07: good (3)
## :      :      :      chlorides > 0.07: normal (4)
## :      :      free.sulfur.dioxide > 27:
## :      :      :...sulphates <= 0.76: good (5)
## :      :      sulphates > 0.76:
## :      :      :...free.sulfur.dioxide <= 30: good (3)
## :      :      free.sulfur.dioxide > 30: normal (6/1)
## :      alcohol <= 11.5:
## :      :...volatile.acidity > 0.4:
## :      :      :...alcohol > 11.4:
## :      :      :      :...free.sulfur.dioxide > 24: normal (2)
## :      :      :      free.sulfur.dioxide <= 24:
## :      :      :      :...residual.sugar <= 3.9: good (5/1)
## :      :      :      residual.sugar > 3.9: normal (2)
## :      :      alcohol <= 11.4:
## :      :      :...sulphates > 0.69: normal (71/4)
## :      :      sulphates <= 0.69:
## :      :      :...pH <= 3.02: good (2)
## :      :      pH > 3.02:
## :      :      :...total.sulfur.dioxide > 33: normal (9)
## :      :      total.sulfur.dioxide <= 33:
## :      :      :...free.sulfur.dioxide <= 9: normal (5)
## :      :      free.sulfur.dioxide > 9: good (4)
## :      volatile.acidity <= 0.4:
## :      :...chlorides > 0.096: normal (7)
## :      chlorides <= 0.096:
## :      :...pH > 3.26:
## :      :      :...residual.sugar > 3.3: good (4)
## :      :      residual.sugar <= 3.3:

```

```

##      :      :      : ...pH <= 3.39: normal (26/4)
##      :      :      pH > 3.39:
##      :      :      : ...alcohol <= 10.9: normal (5/1)
##      :      :      alcohol > 10.9: good (6)
##      :      pH <= 3.26:
##      :      : ...volatile.acidity > 0.38: normal (3)
##      :      volatile.acidity <= 0.38:
##      :      : ...chlorides > 0.076: good (8)
##      :      chlorides <= 0.076:
##      :      : ...chlorides <= 0.06: good (6)
##      :      chlorides > 0.06:
##      :      : ...citric.acid <= 0.48: good (8/2)
##      :      citric.acid > 0.48: normal (4)
## sulphates <= 0.67:
## : ...volatile.acidity > 0.665:
## : ...volatile.acidity <= 1.01: normal (59/8)
## : volatile.acidity > 1.01:
## : : ...residual.sugar <= 1.9: normal (5/1)
## : residual.sugar > 1.9: bad (6)
## volatile.acidity <= 0.665:
## : ...total.sulfur.dioxide > 19:
## : ...residual.sugar > 3.65:
## : : ...volatile.acidity <= 0.38: good (5/1)
## : : volatile.acidity > 0.38: normal (7/1)
## : residual.sugar <= 3.65:
## : : ...chlorides > 0.064: normal (99/1)
## : chlorides <= 0.064:
## : : ...chlorides <= 0.012: good (2)
## : chlorides > 0.012:
## : : ...free.sulfur.dioxide > 19: normal (10)
## : free.sulfur.dioxide <= 19:
## : : ...residual.sugar <= 1.7: good (3)
## : residual.sugar > 1.7: normal (10/1)
## total.sulfur.dioxide <= 19:
## : ...density > 0.9974: normal (11)
## density <= 0.9974:
## : ...residual.sugar > 3.9: good (7/1)
## residual.sugar <= 3.9:
## : ...sulphates <= 0.54: normal (15/1)
## sulphates > 0.54:
## : ...pH <= 3.19: good (7)
## pH > 3.19:
## : ...pH > 3.39:
## : ...residual.sugar <= 2.05: normal (4)
## : residual.sugar > 2.05:
## : : ...sulphates > 0.62: good (3)
## : sulphates <= 0.62:
## : : ...volatile.acidity <= 0.585: bad (3)
## : volatile.acidity > 0.585: normal (3/1)
## pH <= 3.39:
## : ...free.sulfur.dioxide > 8: good (4)
## free.sulfur.dioxide <= 8:
## : ...density <= 0.99331: good (3)
## density > 0.99331:

```

```

##                               :...pH > 3.26: normal (11)
##                               pH <= 3.26: [S1]
##
## SubTree [S1]
##
## free.sulfur.dioxide <= 5.5: normal (3)
## free.sulfur.dioxide > 5.5: good (5/1)
##
##
## Evaluation on training data (1279 cases):
##
##      Decision Tree
##      -----
##      Size      Errors
##
##      62      76( 5.9%)  <<
##
##      (a)      (b)      (c)      <-classified as
##      ----      ----      ----
##      22         2        26      (a): class bad
##              147        32      (b): class good
##              1         15      1034  (c): class normal
##
##
## Attribute usage:
##
## 100.00% alcohol
##  92.18% volatile.acidity
##  63.88% fixed.acidity
##  45.35% sulphates
##  27.29% residual.sugar
##  20.17% pH
##  19.47% total.sulfur.dioxide
##  16.26% chlorides
##  13.14% free.sulfur.dioxide
##   6.18% density
##   0.94% citric.acid
##
##
## Time: 0.0 secs

```

```
# Evaluating model performance
```

```
WineData_predict <- predict(WineData_model, WineData_test)
```

```
# Various R Programming Tools for Model Fitting
```

```
library(gmodels)
```

```
# create a cross tabulation indicating the agreement between the two vectors.
```

```
# Specifying prop.chisq = FALSE will remove the unnecessary chi-square
```

```
# values from the output.
```

```
# Setting the prop.c and prop.r parameters to FALSE removes the column and row percentages
```

```
# from the table. The remaining percentage ( prop.t ) indicates the proportion of
```

```
# records in the cell out of the total number of records:
```

```
CrossTable(WineData_test$quality, WineData_predict, prop.chisq = FALSE, prop.c= FALSE, prop.r = FALSE, c
```

```
##
##
##      Cell Contents
## |-----|
## |                N |
## |      N / Table Total |
## |-----|
##
##
## Total Observations in Table:  320
##
##
##               | Predicted quality
## Actual quality |      bad |      good |      normal | Row Total |
## -----|-----|-----|-----|-----|
##          bad |         1 |         0 |         12 |         13 |
##              |        0.003 |        0.000 |        0.037 |         |
## -----|-----|-----|-----|-----|
##          good |         0 |        22 |         16 |         38 |
##              |        0.000 |        0.069 |        0.050 |         |
## -----|-----|-----|-----|-----|
##          normal |         1 |        15 |        253 |        269 |
##              |        0.003 |        0.047 |        0.791 |         |
## -----|-----|-----|-----|-----|
##      Column Total |         2 |         37 |         281 |        320 |
## -----|-----|-----|-----|-----|
##
##
```

```
# Accuracy : Measures of performance
library(caret)
```

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

```
confusionMatrix(WineData_test$quality, WineData_predict)
```

```
## Confusion Matrix and Statistics
##
##           Reference
## Prediction bad good normal
##      bad      1    0    12
##      good      0   22    16
##      normal     1   15   253
##
## Overall Statistics
##
##           Accuracy : 0.8625
##           95% CI : (0.8198, 0.8983)
##      No Information Rate : 0.8781
##      P-Value [Acc > NIR] : 0.8271
##
##           Kappa : 0.4452
##      McNemar's Test P-Value : NA
```



```
##
## Statistics by Class:
##
##           Class: bad Class: good Class: normal
## Sensitivity      0.500000      0.59459      0.9004
## Specificity      0.962264      0.94346      0.5897
## Pos Pred Value   0.076923      0.57895      0.9405
## Neg Pred Value   0.996743      0.94681      0.4510
## Prevalence       0.006250      0.11563      0.8781
## Detection Rate   0.003125      0.06875      0.7906
## Detection Prevalence 0.040625      0.11875      0.8406
## Balanced Accuracy 0.731132      0.76903      0.7450

# Improving model performance
# Boosting the accuracy of decision trees
# Add additional trials parameter indicating the number of
# separate decision trees to use in the boosted team.
WineData_boost10 <- C5.0(WineData_train[-12], WineData_train$quality, trials = 10)
WineData_boost10

##
## Call:
## C5.0.default(x = WineData_train[-12], y = WineData_train$quality, trials
## = 10)
##
## Classification Tree
## Number of samples: 1279
## Number of predictors: 11
##
## Number of boosting iterations: 10
## Average tree size: 60.3
##
## Non-standard options: attempt to group attributes

# See all 10 trees
summary(WineData_boost10)

##
## Call:
## C5.0.default(x = WineData_train[-12], y = WineData_train$quality, trials
## = 10)
##
##
## C5.0 [Release 2.07 GPL Edition]      Mon Jun  5 18:32:06 2017
## -----
##
## Class specified by attribute `outcome'
##
## Read 1279 cases (12 attributes) from undefined.data
##
## ----- Trial 0: -----
##
## Decision tree:
##
## alcohol <= 10.4:
## ...fixed.acidity > 11.5:
```

```

## :      :...pH > 3.24: bad (2)
## :      :      pH <= 3.24:
## :      :      :...volatile.acidity > 0.32: normal (34/3)
## :      :      volatile.acidity <= 0.32:
## :      :      :...residual.sugar <= 2.4: good (8/2)
## :      :      residual.sugar > 2.4: normal (2)
## :      fixed.acidity <= 11.5:
## :      :...volatile.acidity <= 0.75: normal (597/29)
## :      volatile.acidity > 0.75:
## :      :...pH <= 3.28: normal (33)
## :      pH > 3.28:
## :      :...residual.sugar > 2.25: normal (23/1)
## :      residual.sugar <= 2.25:
## :      :...sulphates > 0.63: normal (4/1)
## :      sulphates <= 0.63:
## :      :...fixed.acidity > 7.4: bad (6)
## :      fixed.acidity <= 7.4:
## :      :...fixed.acidity <= 6.3: bad (2)
## :      fixed.acidity > 6.3:
## :      :...free.sulfur.dioxide <= 11: normal (4)
## :      free.sulfur.dioxide > 11: bad (4/1)
## alcohol > 10.4:
## :...sulphates > 0.67:
## :      :...alcohol > 11.5:
## :      :      :...fixed.acidity > 12.2: normal (5)
## :      :      fixed.acidity <= 12.2:
## :      :      :...free.sulfur.dioxide <= 18: good (60/9)
## :      :      free.sulfur.dioxide > 18:
## :      :      :...residual.sugar > 4.6: good (3)
## :      :      residual.sugar <= 4.6:
## :      :      :...free.sulfur.dioxide <= 27:
## :      :      :...total.sulfur.dioxide > 50: normal (9)
## :      :      total.sulfur.dioxide <= 50:
## :      :      :...chlorides <= 0.07: good (3)
## :      :      chlorides > 0.07: normal (4)
## :      :      free.sulfur.dioxide > 27:
## :      :      :...sulphates <= 0.76: good (5)
## :      :      sulphates > 0.76:
## :      :      :...free.sulfur.dioxide <= 30: good (3)
## :      :      free.sulfur.dioxide > 30: normal (6/1)
## :      alcohol <= 11.5:
## :      :...volatile.acidity > 0.4:
## :      :      :...alcohol > 11.4:
## :      :      :      :...free.sulfur.dioxide > 24: normal (2)
## :      :      :      free.sulfur.dioxide <= 24:
## :      :      :      :...residual.sugar <= 3.9: good (5/1)
## :      :      :      residual.sugar > 3.9: normal (2)
## :      :      alcohol <= 11.4:
## :      :      :...sulphates > 0.69: normal (71/4)
## :      :      sulphates <= 0.69:
## :      :      :...pH <= 3.02: good (2)
## :      :      pH > 3.02:
## :      :      :...total.sulfur.dioxide > 33: normal (9)
## :      :      total.sulfur.dioxide <= 33:

```

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##      :      :      :...free.sulfur.dioxide <= 9: normal (5)
##      :      :      free.sulfur.dioxide > 9: good (4)
##      : volatile.acidity <= 0.4:
##      :      :...chlorides > 0.096: normal (7)
##      :      chlorides <= 0.096:
##      :      :...pH > 3.26:
##      :      :...residual.sugar > 3.3: good (4)
##      :      : residual.sugar <= 3.3:
##      :      :      :...pH <= 3.39: normal (26/4)
##      :      :      pH > 3.39:
##      :      :      :...alcohol <= 10.9: normal (5/1)
##      :      :      alcohol > 10.9: good (6)
##      :      pH <= 3.26:
##      :      :...volatile.acidity > 0.38: normal (3)
##      :      volatile.acidity <= 0.38:
##      :      :...chlorides > 0.076: good (8)
##      :      chlorides <= 0.076:
##      :      :...chlorides <= 0.06: good (6)
##      :      chlorides > 0.06:
##      :      :...citric.acid <= 0.48: good (8/2)
##      :      citric.acid > 0.48: normal (4)
## sulphates <= 0.67:
## :...volatile.acidity > 0.665:
## :...volatile.acidity <= 1.01: normal (59/8)
## : volatile.acidity > 1.01:
## :      :...residual.sugar <= 1.9: normal (5/1)
## :      residual.sugar > 1.9: bad (6)
## volatile.acidity <= 0.665:
## :...total.sulfur.dioxide > 19:
## :...residual.sugar > 3.65:
## :      :...volatile.acidity <= 0.38: good (5/1)
## :      : volatile.acidity > 0.38: normal (7/1)
## :      residual.sugar <= 3.65:
## :      :...chlorides > 0.064: normal (99/1)
## :      chlorides <= 0.064:
## :      :...chlorides <= 0.012: good (2)
## :      chlorides > 0.012:
## :      :...free.sulfur.dioxide > 19: normal (10)
## :      free.sulfur.dioxide <= 19:
## :      :...residual.sugar <= 1.7: good (3)
## :      residual.sugar > 1.7: normal (10/1)
## total.sulfur.dioxide <= 19:
## :...density > 0.9974: normal (11)
## density <= 0.9974:
## :...residual.sugar > 3.9: good (7/1)
## residual.sugar <= 3.9:
## :...sulphates <= 0.54: normal (15/1)
## sulphates > 0.54:
## :...pH <= 3.19: good (7)
## pH > 3.19:
## :...pH > 3.39:
## :...residual.sugar <= 2.05: normal (4)
## : residual.sugar > 2.05:
## :      :...sulphates > 0.62: good (3)

```

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##          :      sulphates <= 0.62:
##          :      :...volatile.acidity <= 0.585: bad (3)
##          :      volatile.acidity > 0.585: normal (3/1)
##          pH <= 3.39:
##          :...free.sulfur.dioxide > 8: good (4)
##          free.sulfur.dioxide <= 8:
##          :...density <= 0.99331: good (3)
##          density > 0.99331:
##          :...pH > 3.26: normal (11)
##          pH <= 3.26: [S1]
##
## SubTree [S1]
##
## free.sulfur.dioxide <= 5.5: normal (3)
## free.sulfur.dioxide > 5.5: good (5/1)
##
## ----- Trial 1: -----
##
## Decision tree:
##
## sulphates <= 0.64:
## :...residual.sugar > 3.3:
## : :...alcohol > 12: good (8.4/3.1)
## : : alcohol <= 12:
## : : :...density <= 0.99574: bad (25.1/1.5)
## : : density > 0.99574:
## : : :...residual.sugar > 4.5: normal (25.3/1.5)
## : : residual.sugar <= 4.5:
## : : :...residual.sugar <= 4.1: normal (22.3/5.5)
## : : residual.sugar > 4.1: bad (14.9)
## : residual.sugar <= 3.3:
## : :...alcohol > 11:
## : : :...sulphates <= 0.53: normal (23/1.5)
## : : sulphates > 0.53:
## : : :...volatile.acidity > 0.915: bad (3.1/1.5)
## : : volatile.acidity <= 0.915:
## : : :...volatile.acidity > 0.805: good (4.7)
## : : volatile.acidity <= 0.805:
## : : :...total.sulfur.dioxide <= 14: good (27.8/10.7)
## : : total.sulfur.dioxide > 14: normal (54.7/11.7)
## : alcohol <= 11:
## : :...chlorides <= 0.061:
## : : :...pH <= 3.52: normal (27.8/11.7)
## : : pH > 3.52: bad (10.2)
## : : chlorides > 0.061:
## : : :...free.sulfur.dioxide > 17: normal (135.7/5.5)
## : : free.sulfur.dioxide <= 17:
## : : :...alcohol <= 9.3:
## : : :...alcohol <= 8.7: bad (4.7)
## : : alcohol > 8.7:
## : : :...free.sulfur.dioxide <= 16: normal (49.2/10.2)
## : : free.sulfur.dioxide > 16: bad (10.2/0.8)
## : alcohol > 9.3:
## : :...total.sulfur.dioxide <= 14:

```

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## :                :...pH <= 3.28: normal (10.7)
## :                :   pH > 3.28: bad (27.1/10)
## :                total.sulfur.dioxide > 14:
## :                :...sulphates > 0.61:
## :                :...free.sulfur.dioxide <= 11: normal (13)
## :                :   free.sulfur.dioxide > 11: good (23.3/9.2)
## :                sulphates <= 0.61:
## :                :...citric.acid <= 0.35:
## :                :...residual.sugar <= 1.3: good (5.5/0.8)
## :                :   residual.sugar > 1.3: normal (148.1/15.5)
## :                citric.acid > 0.35:
## :                :...volatile.acidity <= 0.585: normal (20.7)
## :                :   volatile.acidity > 0.585: bad (11.7/2.3)
## sulphates > 0.64:
## :...sulphates > 1.07:
## :   :...citric.acid <= 0.21: bad (9.4)
## :   :   citric.acid > 0.21: normal (19.1/2.3)
## :   sulphates <= 1.07:
## :   :...alcohol <= 9.8: normal (112.9/11.7)
## :   :   alcohol > 9.8:
## :   :...chlorides > 0.122: normal (25.6/12.5)
## :   :   chlorides <= 0.122:
## :   :...volatile.acidity > 0.41:
## :   :   :...density <= 0.9934: good (10)
## :   :   :   density > 0.9934:
## :   :   :   :...chlorides > 0.106: good (22.5/6.1)
## :   :   :   :   chlorides <= 0.106:
## :   :   :   :   :...fixed.acidity <= 6.5: normal (23.1)
## :   :   :   :   :   fixed.acidity > 6.5:
## :   :   :   :   :   :...total.sulfur.dioxide > 78: normal (15.3)
## :   :   :   :   :   :   total.sulfur.dioxide <= 78:
## :   :   :   :   :   :   :...free.sulfur.dioxide > 28: good (20.9/6.1)
## :   :   :   :   :   :   :   free.sulfur.dioxide <= 28:
## :   :   :   :   :   :   :   :...free.sulfur.dioxide <= 4: good (5.5/0.8)
## :   :   :   :   :   :   :   :   free.sulfur.dioxide > 4: normal (101.8/23.2)
## :   :   :   volatile.acidity <= 0.41:
## :   :   :   :...volatile.acidity <= 0.24: normal (35.7/6.9)
## :   :   :   :   volatile.acidity > 0.24:
## :   :   :   :   :...total.sulfur.dioxide > 53:
## :   :   :   :   :   :...volatile.acidity <= 0.28: good (10.2/0.8)
## :   :   :   :   :   :   :   volatile.acidity > 0.28: normal (24.5/1.5)
## :   :   :   :   total.sulfur.dioxide <= 53:
## :   :   :   :   :...citric.acid <= 0.31: good (20.4/0.8)
## :   :   :   :   :   citric.acid > 0.31:
## :   :   :   :   :   :...alcohol > 12.2: good (18.5/1.5)
## :   :   :   :   :   :   alcohol <= 12.2:
## :   :   :   :   :   :   :...residual.sugar <= 1.5: good (12.5/1.5)
## :   :   :   :   :   :   :   residual.sugar > 1.5:
## :   :   :   :   :   :   :   :...residual.sugar > 4.65: good (3.8)
## :   :   :   :   :   :   :   :   residual.sugar <= 4.65:
## :   :   :   :   :   :   :   :   :...volatile.acidity > 0.38: normal (10.7/0.8)
## :   :   :   :   :   :   :   :   :   volatile.acidity <= 0.38:
## :   :   :   :   :   :   :   :   :   :...density <= 0.9954: good (16.2/2.3)
## :   :   :   :   :   :   :   :   :   :   density > 0.9954: [S1]

```

```

##
## SubTree [S1]
##
## chlorides <= 0.077: normal (34/6.9)
## chlorides > 0.077: good (19.3/5.4)
##
## ----- Trial 2: -----
##
## Decision tree:
##
## sulphates <= 0.64:
## :...alcohol > 11.5:
## :   :...residual.sugar > 4.25: bad (17.9/10.5)
## :   :   residual.sugar <= 4.25:
## :   :     :...alcohol <= 11.7: good (15.3/3)
## :   :     :   alcohol > 11.7:
## :   :       :...sulphates > 0.63: good (6.6)
## :   :       :   sulphates <= 0.63:
## :   :           :...volatile.acidity <= 0.79: normal (52.5/7.5)
## :   :           :   volatile.acidity > 0.79: good (5/1.2)
## :   alcohol <= 11.5:
## :   :...volatile.acidity > 0.665:
## :       :...total.sulfur.dioxide > 86: normal (20)
## :       :   total.sulfur.dioxide <= 86:
## :       :     :...alcohol > 10.9:
## :       :       :...chlorides <= 0.064: normal (4.3)
## :       :       :   chlorides > 0.064: bad (25.6/3)
## :       :       :   alcohol <= 10.9:
## :       :           :...volatile.acidity <= 0.675: bad (16.3/4.3)
## :       :           :   volatile.acidity > 0.675:
## :       :               :...chlorides <= 0.062: bad (20.1/1.8)
## :       :               :   chlorides > 0.062:
## :       :                   :...alcohol > 9.8: normal (44/1.2)
## :       :                   :   alcohol <= 9.8:
## :       :                       :...volatile.acidity <= 0.75: normal (24.8)
## :       :                       :   volatile.acidity > 0.75:
## :       :                           :...pH <= 3.28: normal (10)
## :       :                           :   pH > 3.28: bad (20.6/6.9)
## :   volatile.acidity <= 0.665:
## :       :...total.sulfur.dioxide > 55:
## :           :...residual.sugar <= 11: normal (112.7)
## :           :   residual.sugar > 11: bad (4.3/0.6)
## :       total.sulfur.dioxide <= 55:
## :           :...alcohol <= 9.3:
## :               :...sulphates <= 0.51: bad (20.3/3)
## :               :   sulphates > 0.51: normal (24.7/5.8)
## :           alcohol > 9.3:
## :               :...total.sulfur.dioxide > 46:
## :                   :...sulphates <= 0.57: bad (21.5/4.3)
## :                   :   sulphates > 0.57: normal (14.1/3.7)
## :               total.sulfur.dioxide <= 46:
## :                   :...chlorides > 0.095:
## :                       :...pH <= 3.32: normal (16.7)
## :                       :   pH > 3.32: bad (18.2/6.6)

```

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## : chlorides <= 0.095:
## : ...pH > 3.6: normal (9.9/3.7)
## : pH <= 3.6:
## : ...chlorides > 0.09: good (15.5/3.7)
## : chlorides <= 0.09:
## : ...density > 0.9968: normal (44.4)
## : density <= 0.9968:
## : ...free.sulfur.dioxide > 15: normal (17.6)
## : free.sulfur.dioxide <= 15:
## : ...density > 0.99675: good (11/1.2)
## : density <= 0.99675:
## : ...alcohol <= 9.9: normal (19.1)
## : alcohol > 9.9:
## : ...chlorides <= 0.066: good (20.6/5.7)
## : chlorides > 0.066: [S1]
## sulphates > 0.64:
## ...alcohol <= 9.9:
## : ...volatile.acidity <= 0.415:
## : : ...total.sulfur.dioxide <= 19: normal (16)
## : : total.sulfur.dioxide > 19:
## : : ...total.sulfur.dioxide <= 42: good (28/7.9)
## : : total.sulfur.dioxide > 42: normal (12.2)
## : volatile.acidity > 0.415:
## : ...volatile.acidity > 0.855: bad (7.2/1.2)
## : volatile.acidity <= 0.855:
## : ...residual.sugar <= 1.65: bad (14.4/4.9)
## : residual.sugar > 1.65: normal (60.1)
## alcohol > 9.9:
## ...chlorides > 0.122:
## : ...chlorides <= 0.123: bad (6)
## : chlorides > 0.123: good (22.7/10.4)
## chlorides <= 0.122:
## ...sulphates > 0.84:
## : ...pH <= 3.11: normal (8)
## : pH > 3.11:
## : ...total.sulfur.dioxide <= 13: normal (5)
## : total.sulfur.dioxide > 13:
## : ...alcohol > 11.9: good (19.9/0.6)
## : alcohol <= 11.9:
## : ...residual.sugar > 3.1: normal (6.8)
## : residual.sugar <= 3.1:
## : ...sulphates <= 1.05: good (52.7/14.5)
## : sulphates > 1.05: normal (3)
## sulphates <= 0.84:
## ...total.sulfur.dioxide <= 12: good (26.2/6)
## : total.sulfur.dioxide > 12:
## : ...total.sulfur.dioxide > 59:
## : : ...volatile.acidity <= 0.33: good (12.4/4.5)
## : : volatile.acidity > 0.33: normal (36.3/2.4)
## : total.sulfur.dioxide <= 59:
## : ...residual.sugar > 4.8: good (8.4/0.6)
## : residual.sugar <= 4.8:
## : ...chlorides > 0.071:
## : ...residual.sugar <= 2.25:

```

```

##          :   ...volatile.acidity <= 0.16: good (4.1)
##          :   :   volatile.acidity > 0.16: normal (55.8/5.4)
##          :   residual.sugar > 2.25:
##          :   ...sulphates <= 0.68: normal (23.5/4.5)
##          :       sulphates > 0.68:
##          :           ...density > 1.0002: normal (6.3)
##          :           density <= 1.0002:
##          :               ...sulphates > 0.8: normal (4.5)
##          :               sulphates <= 0.8: [S2]
##          chlorides <= 0.071:
##          ...density > 0.99733: normal (9.2)
##          density <= 0.99733:
##          ...pH <= 3.16: good (12.8)
##          pH > 3.16:
##          ...density > 0.99661: good (16.8/1.2)
##          density <= 0.99661:
##          ...density > 0.99555: normal (12.6)
##          density <= 0.99555:
##          ...sulphates <= 0.67: normal (4.5)
##          sulphates > 0.67: [S3]
##
## SubTree [S1]
##
## volatile.acidity <= 0.575: normal (26.8/1.2)
## volatile.acidity > 0.575: good (10.9/3)
##
## SubTree [S2]
##
## free.sulfur.dioxide <= 26: good (40.5/6.7)
## free.sulfur.dioxide > 26: normal (6/0.6)
##
## SubTree [S3]
##
## volatile.acidity <= 0.19: normal (5.6)
## volatile.acidity > 0.19:
## :...free.sulfur.dioxide <= 24: good (32.4/8.6)
##     free.sulfur.dioxide > 24: normal (7.8/1.2)
##
## ----- Trial 3: -----
##
## Decision tree:
##
## sulphates <= 0.61:
## :...alcohol > 11:
## :   :...pH <= 3.27:
## :   :   :...chlorides <= 0.11: good (36.8/12.2)
## :   :   :   chlorides > 0.11: normal (7.8)
## :   :   pH > 3.27:
## :   :   :...residual.sugar > 3.8: bad (24.8/10.1)
## :   :   residual.sugar <= 3.8:
## :   :       :...total.sulfur.dioxide <= 8: good (5.2/1.6)
## :   :       total.sulfur.dioxide > 8:
## :   :       :...free.sulfur.dioxide <= 31: normal (66.1/3.9)
## :   :       free.sulfur.dioxide > 31: good (2.9)

```



```

## : alcohol <= 11:
## : :...total.sulfur.dioxide > 85: normal (47.6)
## : total.sulfur.dioxide <= 85:
## : :...total.sulfur.dioxide <= 9: bad (14.4/3.4)
## : total.sulfur.dioxide > 9:
## : :...alcohol <= 9.3:
## : :...free.sulfur.dioxide > 18: normal (11.6)
## : : free.sulfur.dioxide <= 18:
## : : :...volatile.acidity > 0.675: normal (8.2)
## : : volatile.acidity <= 0.675:
## : : :...fixed.acidity <= 7.2: normal (6.2)
## : : fixed.acidity > 7.2:
## : : :...pH <= 3.15: normal (3.2)
## : : pH > 3.15: bad (33.3/7.1)
## : alcohol > 9.3:
## : :...volatile.acidity > 0.75:
## : : :...pH > 3.57: bad (5.2)
## : : pH <= 3.57:
## : : :...alcohol <= 10.9: normal (52.6/12.3)
## : : alcohol > 10.9: bad (7.2/1)
## : volatile.acidity <= 0.75:
## : :...total.sulfur.dioxide > 46:
## : : :...chlorides <= 0.07: bad (14.3/3.7)
## : : chlorides > 0.07: normal (54.2/2.9)
## : total.sulfur.dioxide <= 46:
## : :...free.sulfur.dioxide <= 8: normal (60/4.7)
## : free.sulfur.dioxide > 8:
## : :...total.sulfur.dioxide <= 21: good (18.5/4.3)
## : total.sulfur.dioxide > 21: normal (63.6/4.7)
## sulphates > 0.61:
## :...alcohol <= 9.8:
## : :...volatile.acidity <= 0.605:
## : : :...density > 0.9968: normal (86.1/6.5)
## : : density <= 0.9968:
## : : :...density <= 0.99678: normal (20.6)
## : : density > 0.99678: good (7.7)
## : volatile.acidity > 0.605:
## : :...residual.sugar <= 1.5: bad (5.9)
## : residual.sugar > 1.5:
## : :...alcohol <= 8.7: bad (4.9)
## : alcohol > 8.7:
## : :...pH <= 3.59: normal (33.5)
## : pH > 3.59: bad (6.2/1.4)
## alcohol > 9.8:
## :...pH > 3.42:
## : :...alcohol > 12.1: good (28.5/3.8)
## : alcohol <= 12.1:
## : :...sulphates > 0.67: normal (59.9/17.3)
## : sulphates <= 0.67:
## : :...free.sulfur.dioxide > 14: normal (11.1)
## : free.sulfur.dioxide <= 14:
## : :...citric.acid <= 0.3: bad (25.6/6.6)
## : citric.acid > 0.3: normal (4.2)
## pH <= 3.42:

```

```

##      :...chlorides > 0.143: normal (18.9/3.3)
##      chlorides <= 0.143:
##      :...pH <= 3.05: good (23/4.8)
##      pH > 3.05:
##      :...pH <= 3.13: normal (23.9/2.3)
##      pH > 3.13:
##      :...total.sulfur.dioxide > 54:
##      :...fixed.acidity <= 8.4: normal (34.2)
##      :   fixed.acidity > 8.4:
##      :   :...residual.sugar <= 1.8: good (6.2)
##      :   :   residual.sugar > 1.8:
##      :   :   :...free.sulfur.dioxide <= 34: normal (24.1/3.7)
##      :   :   :   free.sulfur.dioxide > 34: good (5.3/1)
##      total.sulfur.dioxide <= 54:
##      :...alcohol > 11.5:
##      :   :...pH <= 3.21: good (10.7)
##      :   :   pH > 3.21:
##      :   :   :...fixed.acidity <= 8.3: good (23.8/2.4)
##      :   :   :   fixed.acidity > 8.3:
##      :   :   :   :...residual.sugar > 2.9: good (10.2/1)
##      :   :   :   :   residual.sugar <= 2.9:
##      :   :   :   :   :...volatile.acidity <= 0.16: good (3.3)
##      :   :   :   :   :   volatile.acidity > 0.16:
##      :   :   :   :   :   :...alcohol <= 11.6: good (3.4)
##      :   :   :   :   :   :   alcohol > 11.6: normal (45.2/9.3)
##      alcohol <= 11.5:
##      :...volatile.acidity <= 0.23: normal (9.9)
##      :   volatile.acidity > 0.23:
##      :   :...citric.acid > 0.47: normal (48.8/9.7)
##      :   :   citric.acid <= 0.47:
##      :   :   :...pH <= 3.15: good (9.6)
##      :   :   :   pH > 3.15:
##      :   :   :   :...volatile.acidity <= 0.43: [S1]
##      :   :   :   :   volatile.acidity > 0.43:
##      :   :   :   :   :...alcohol > 10.6: normal (37.4/1.6)
##      :   :   :   :   :   alcohol <= 10.6: [S2]
##
## SubTree [S1]
##
## free.sulfur.dioxide <= 21: good (55.6/13.4)
## free.sulfur.dioxide > 21: normal (13.8/1.9)
##
## SubTree [S2]
##
## fixed.acidity <= 8.7: good (26.8/5.6)
## fixed.acidity > 8.7: normal (7.1)
##
## ----- Trial 4: -----
##
## Decision tree:
##
## sulphates <= 0.64:
## :...alcohol > 11.5:
## :   :...sulphates <= 0.61: normal (87.5/23.3)

```

```

## :      :   sulphates > 0.61:
## :      :   :...chlorides <= 0.05: normal (5.4)
## :      :       chlorides > 0.05: good (26.3/7.6)
## :      alcohol <= 11.5:
## :      :...volatile.acidity > 0.665:
## :          :...total.sulfur.dioxide <= 9: bad (6.4)
## :          :   total.sulfur.dioxide > 9:
## :          :       :...volatile.acidity > 0.915:
## :          :           :...alcohol <= 9.2: normal (3.2)
## :          :           :   alcohol > 9.2:
## :          :           :       :...citric.acid > 0.22: normal (4.1)
## :          :           :           citric.acid <= 0.22:
## :          :           :       :...volatile.acidity <= 1.24: bad (30.2/4.8)
## :          :           :           volatile.acidity > 1.24: normal (2.6)
## :          :       volatile.acidity <= 0.915:
## :          :       :...alcohol <= 9.233334: bad (11.2/3.8)
## :          :           alcohol > 9.233334:
## :          :           :...volatile.acidity <= 0.75: normal (55.4/2.3)
## :          :           :       volatile.acidity > 0.75:
## :          :           :       :...chlorides > 0.25: bad (2.9)
## :          :           :           chlorides <= 0.25:
## :          :           :       :...sulphates <= 0.5: bad (16.5/6.5)
## :          :           :           sulphates > 0.5: normal (45/6.8)
## :      volatile.acidity <= 0.665:
## :      :...total.sulfur.dioxide > 55: normal (86.6/2.3)
## :      :   total.sulfur.dioxide <= 55:
## :      :       :...chlorides > 0.101:
## :      :           :...total.sulfur.dioxide <= 17: bad (20.2/6.8)
## :      :           :       total.sulfur.dioxide > 17: normal (8.7)
## :      :       chlorides <= 0.101:
## :      :       :...free.sulfur.dioxide > 13:
## :      :           :...residual.sugar <= 1.4: good (3.1/0.8)
## :      :           :       residual.sugar > 1.4:
## :      :           :       :...sulphates > 0.57: normal (29.6)
## :      :           :           sulphates <= 0.57:
## :      :           :       :...alcohol > 10.4: normal (13.5)
## :      :           :           alcohol <= 10.4:
## :      :           :       :...citric.acid <= 0.23: normal (14.5/2.3)
## :      :           :           citric.acid > 0.23: bad (24/5.4)
## :      :       free.sulfur.dioxide <= 13:
## :      :       :...pH > 3.61: bad (6.4/1.3)
## :      :           pH <= 3.61:
## :      :           :...free.sulfur.dioxide <= 8: normal (90/11.2)
## :      :           :       free.sulfur.dioxide > 8:
## :      :           :       :...citric.acid > 0.62: bad (2.6)
## :      :           :           citric.acid <= 0.62:
## :      :           :       :...total.sulfur.dioxide <= 18: good (13.5/0.4)
## :      :           :           total.sulfur.dioxide > 18:
## :      :           :       :...sulphates <= 0.59: normal (32.4/1.3)
## :      :           :           sulphates > 0.59: good (26.5/10)
## sulphates > 0.64:
## :...alcohol <= 9.9:
## :...fixed.acidity <= 11.5: normal (99.1/12.1)
## :   fixed.acidity > 11.5: good (26.9/11.5)

```

```

##      alcohol > 9.9:
##      :...chlorides > 0.121:
##      :    :...pH > 3.48: bad (3.7)
##      :    :    pH <= 3.48:
##      :    :    :...volatile.acidity <= 0.815: normal (27.4/5.5)
##      :    :    :    volatile.acidity > 0.815: good (3.7)
##      chlorides <= 0.121:
##      :...fixed.acidity <= 7.1:
##      :    :...chlorides > 0.119: good (4.3)
##      :    :    chlorides <= 0.119:
##      :    :    :...density > 0.99552: normal (20.5)
##      :    :    :    density <= 0.99552:
##      :    :    :    :...total.sulfur.dioxide > 83: good (6.9/0.8)
##      :    :    :    :    total.sulfur.dioxide <= 83:
##      :    :    :    :    :...density <= 0.99549: normal (51.3/10.5)
##      :    :    :    :    :    density > 0.99549: good (3.6)
##      fixed.acidity > 7.1:
##      :...fixed.acidity <= 7.4:
##      :    :...total.sulfur.dioxide <= 62: good (26.6/2.5)
##      :    :    total.sulfur.dioxide > 62: normal (4.3)
##      fixed.acidity > 7.4:
##      :...free.sulfur.dioxide > 43: good (11.2/1.4)
##      :    free.sulfur.dioxide <= 43:
##      :    :...total.sulfur.dioxide > 59: normal (31.6/4.5)
##      :    :    total.sulfur.dioxide <= 59:
##      :    :    :...alcohol <= 11.1:
##      :    :    :    :...volatile.acidity > 0.64: normal (11.9)
##      :    :    :    :    volatile.acidity <= 0.64:
##      :    :    :    :    :...citric.acid <= 0.18: good (8.4)
##      :    :    :    :    :    citric.acid > 0.18:
##      :    :    :    :    :    :...fixed.acidity <= 9.5: normal (46.7/3.2)
##      :    :    :    :    :    :    fixed.acidity > 9.5:
##      :    :    :    :    :    :    :...total.sulfur.dioxide > 32: [S1]
##      :    :    :    :    :    :    :    total.sulfur.dioxide <= 32:
##      :    :    :    :    :    :    :    :...pH > 3.25: normal (4.3)
##      :    :    :    :    :    :    :    :    pH <= 3.25: [S2]
##      alcohol > 11.1:
##      :...free.sulfur.dioxide <= 3: normal (5.1)
##      :    free.sulfur.dioxide > 3:
##      :    :...total.sulfur.dioxide <= 12: good (10.8)
##      :    :    total.sulfur.dioxide > 12:
##      :    :    :...volatile.acidity <= 0.33:
##      :    :    :    :...sulphates <= 0.73: normal (9.7/2.2)
##      :    :    :    :    sulphates > 0.73: [S3]
##      :    :    :    volatile.acidity > 0.33:
##      :    :    :    :...residual.sugar <= 2.35:
##      :    :    :    :    :...alcohol <= 12.5: normal (29/0.4)
##      :    :    :    :    :    alcohol > 12.5: good (3.2)
##      :    :    :    :    :    :    residual.sugar > 2.35: [S4]
##
## SubTree [S1]
##
## residual.sugar <= 1.5: good (4.4)
## residual.sugar > 1.5: normal (29.3/6.4)

```

```

##
## SubTree [S2]
##
## volatile.acidity <= 0.44: good (38.5/5)
## volatile.acidity > 0.44: normal (3.7)
##
## SubTree [S3]
##
## total.sulfur.dioxide <= 55: good (32.1)
## total.sulfur.dioxide > 55: normal (2.3)
##
## SubTree [S4]
##
## residual.sugar > 3.9: normal (12.5/3.7)
## residual.sugar <= 3.9:
## :...sulphates <= 0.91: good (34.6/4.5)
##     sulphates > 0.91: normal (3.2)
##
## ----- Trial 5: -----
##
## Decision tree:
##
## sulphates <= 0.64:
## :...alcohol <= 10.9:
## : : ...total.sulfur.dioxide <= 14:
## : : : ...pH <= 3.28: normal (15.6)
## : : : pH > 3.28:
## : : : : ...density <= 0.9952: bad (8.7)
## : : : : density > 0.9952:
## : : : : : ...density <= 0.99586: normal (8.5)
## : : : : : density > 0.99586:
## : : : : : : ...chlorides <= 0.056: normal (3.6)
## : : : : : : chlorides > 0.056:
## : : : : : : : ...chlorides <= 0.078: bad (12.8)
## : : : : : : : chlorides > 0.078: normal (19.2/7.7)
## : : : total.sulfur.dioxide > 14:
## : : : : ...alcohol > 9.4:
## : : : : : ...sulphates > 0.57: normal (106.7/14)
## : : : : : sulphates <= 0.57:
## : : : : : : ...chlorides > 0.143: bad (5.2/0.6)
## : : : : : : chlorides <= 0.143:
## : : : : : : : ...fixed.acidity <= 7.2: normal (43/1.8)
## : : : : : : : fixed.acidity > 7.2:
## : : : : : : : : ...pH <= 3.28: normal (56.6/1.8)
## : : : : : : : pH > 3.28:
## : : : : : : : : ...pH <= 3.31: bad (18.8/6.7)
## : : : : : : : pH > 3.31: normal (38.5/12)
## : : : : alcohol <= 9.4:
## : : : : : ...free.sulfur.dioxide > 17: normal (32.4)
## : : : : : free.sulfur.dioxide <= 17:
## : : : : : : ...alcohol <= 8.7: bad (3.1)
## : : : : : : alcohol > 8.7:
## : : : : : : : ...residual.sugar > 3.9: bad (3.8)
## : : : : : : : residual.sugar <= 3.9:

```

```

## : : :...free.sulfur.dioxide <= 9: normal (25.3)
## : : free.sulfur.dioxide > 9:
## : : :...free.sulfur.dioxide > 16: bad (6.6/1)
## : : free.sulfur.dioxide <= 16:
## : : :...free.sulfur.dioxide > 14: normal (15)
## : : free.sulfur.dioxide <= 14:
## : : :...fixed.acidity <= 8.2: normal (19.2/2.3)
## : : fixed.acidity > 8.2: bad (13.2/2.4)
## : alcohol > 10.9:
## : :...volatile.acidity > 0.665:
## : : :...free.sulfur.dioxide > 31: good (4.8/1)
## : : free.sulfur.dioxide <= 31:
## : : :...chlorides > 0.093: bad (6.7)
## : : chlorides <= 0.093:
## : : :...volatile.acidity <= 0.685: bad (7.9/0.3)
## : : volatile.acidity > 0.685:
## : : :...volatile.acidity <= 1.01: normal (30.2/1.8)
## : : volatile.acidity > 1.01: bad (4.9)
## : volatile.acidity <= 0.665:
## : :...residual.sugar > 6.2: bad (15.6/8)
## : residual.sugar <= 6.2:
## : :...chlorides <= 0.012: good (5.5)
## : chlorides > 0.012:
## : :...residual.sugar > 4.8: good (8.3/0.3)
## : residual.sugar <= 4.8:
## : :...total.sulfur.dioxide <= 10: good (38.8/13.2)
## : total.sulfur.dioxide > 10:
## : :...sulphates <= 0.54: normal (22.7)
## : sulphates > 0.54:
## : :...citric.acid > 0.72: good (2.9)
## : citric.acid <= 0.72:
## : :...density > 0.99517: normal (33.9/2)
## : density <= 0.99517:
## : :...sulphates <= 0.55: good (6.5/0.3)
## : sulphates > 0.55:
## : :...sulphates > 0.63: good (3.2)
## : sulphates <= 0.63:
## : :...pH <= 3.17: good (2.7)
## : pH > 3.17: normal (37.4/9.3)
## sulphates > 0.64:
## :...alcohol <= 9.9:
## : :...free.sulfur.dioxide > 25: bad (24.4/11)
## : free.sulfur.dioxide <= 25:
## : :...residual.sugar <= 1.3: bad (3.8)
## : residual.sugar > 1.3:
## : :...fixed.acidity > 14.3: good (4.6)
## : fixed.acidity <= 14.3:
## : :...alcohol <= 9.6: normal (48)
## : alcohol > 9.6:
## : :...chlorides <= 0.073: good (8.9/1.4)
## : chlorides > 0.073: normal (32.2/5.2)
## alcohol > 9.9:
## :...sulphates <= 0.67:
## : :...chlorides > 0.122: bad (5.9/2.9)

```

```

##      : chlorides <= 0.122:
##      :      ...sulphates > 0.66: normal (14.4/1)
##      :      sulphates <= 0.66:
##      :      ...free.sulfur.dioxide <= 5.5: good (7.6)
##      :      free.sulfur.dioxide > 5.5: normal (39.5/9.1)
## sulphates > 0.67:
##      ...citric.acid > 0.69: good (13.7/1)
##      citric.acid <= 0.69:
##      ...fixed.acidity > 12: normal (20)
##      fixed.acidity <= 12:
##      ...alcohol > 11.5:
##      ...free.sulfur.dioxide <= 13: good (70.6/14)
##      : free.sulfur.dioxide > 13:
##      :      ...volatile.acidity <= 0.39: normal (23.1/6.2)
##      :      volatile.acidity > 0.39: good (28.1/7.8)
##      alcohol <= 11.5:
##      ...chlorides > 0.12: normal (15.2/0.3)
##      chlorides <= 0.12:
##      ...chlorides > 0.082:
##      ...residual.sugar > 5.15: good (7.8)
##      : residual.sugar <= 5.15:
##      :      ...sulphates <= 0.69: normal (5.2)
##      :      sulphates > 0.69:
##      :      ...citric.acid > 0.53: good (11.4)
##      :      citric.acid <= 0.53: [S1]
##      chlorides <= 0.082:
##      ...residual.sugar > 2.25:
##      ...pH <= 3.57: normal (42.5/2.9)
##      : pH > 3.57: good (4.6)
##      residual.sugar <= 2.25:
##      ...chlorides > 0.077: normal (16.7/0.3)
##      chlorides <= 0.077:
##      ...citric.acid <= 0.14: normal (15.1)
##      citric.acid > 0.14:
##      ...density > 0.99803: normal (6.3)
##      density <= 0.99803:
##      ...sulphates > 1.05: normal (3.6)
##      sulphates <= 1.05: [S2]
##
## SubTree [S1]
##
## free.sulfur.dioxide <= 13: normal (5)
## free.sulfur.dioxide > 13: good (33.7/11)
##
## SubTree [S2]
##
## free.sulfur.dioxide <= 5.5: normal (11.7/3.8)
## free.sulfur.dioxide > 5.5:
## ...residual.sugar > 1.9: good (26.3/1.2)
##      residual.sugar <= 1.9:
##      ...citric.acid <= 0.19: good (6.2)
##      citric.acid > 0.19:
##      ...citric.acid <= 0.28: normal (2.8)
##      citric.acid > 0.28:

```

```

##           :...pH <= 3.27: good (22.3/3.1)
##           pH > 3.27: normal (9.8/2.3)
##
## ----- Trial 6: -----
##
## Decision tree:
##
## volatile.acidity > 0.66:
## :...alcohol > 12: good (12.7/5.7)
## :   alcohol <= 12:
## :     :...sulphates > 0.64:
## :       :...volatile.acidity > 0.9: good (4.6/0.2)
## :       :   volatile.acidity <= 0.9:
## :       :     :...residual.sugar <= 1.4: bad (3)
## :       :     residual.sugar > 1.4: normal (42.6/7.5)
## :     sulphates <= 0.64:
## :       :...pH <= 3.28: normal (39.8/2.3)
## :       pH > 3.28:
## :         :...volatile.acidity <= 0.75: normal (55.4/10.6)
## :         volatile.acidity > 0.75:
## :           :...residual.sugar <= 1.5: bad (6.9)
## :           residual.sugar > 1.5:
## :             :...density <= 0.99557: normal (20.5/2)
## :             density > 0.99557:
## :               :...pH > 3.56: bad (7.3)
## :               pH <= 3.56:
## :                 :...residual.sugar > 2.25: normal (27.6/8)
## :                 residual.sugar <= 2.25:
## :                   :...chlorides <= 0.09: bad (25.5/3.3)
## :                   chlorides > 0.09: normal (3.3)
## volatile.acidity <= 0.66:
## :...alcohol <= 10.4:
## :   :...alcohol <= 9.1:
## :     :   :...volatile.acidity <= 0.545: normal (23.6)
## :     :     :   volatile.acidity > 0.545: bad (19.7/6.8)
## :     :   alcohol > 9.1:
## :     :     :...total.sulfur.dioxide > 67: normal (85.1)
## :     :     total.sulfur.dioxide <= 67:
## :     :       :...sulphates <= 0.57:
## :     :         :...citric.acid <= 0.23:
## :     :         :   :...sulphates > 0.56: good (4.6/0.2)
## :     :         :     :   sulphates <= 0.56:
## :     :         :       :   :...residual.sugar <= 1.2: good (3.3)
## :     :         :       :   residual.sugar > 1.2: normal (32)
## :     :         :     citric.acid > 0.23:
## :     :         :       :...residual.sugar <= 1.9: normal (6.8)
## :     :         :       residual.sugar > 1.9:
## :     :         :         :...residual.sugar > 3.65: bad (3.3)
## :     :         :         residual.sugar <= 3.65:
## :     :         :           :...pH <= 3.22: normal (6.6)
## :     :         :           pH > 3.22:
## :     :         :             :...chlorides <= 0.085: normal (21.8/8.1)
## :     :         :             chlorides > 0.085: bad (12.9/0.7)
## :     :       sulphates > 0.57:

```



```

##      :      :...free.sulfur.dioxide > 35: bad (7.9/4.4)
##      :      free.sulfur.dioxide <= 35:
##      :      :...free.sulfur.dioxide <= 9: normal (68.2/9)
##      :      free.sulfur.dioxide > 9:
##      :      :...residual.sugar > 2.65: normal (24.6/2.6)
##      :      residual.sugar <= 2.65:
##      :      :...density <= 0.99654: normal (27.6/1.4)
##      :      density > 0.99654:
##      :      :...citric.acid > 0.54: normal (5.5)
##      :      citric.acid <= 0.54:
##      :      :...pH > 3.32: normal (33.4/8.1)
##      :      pH <= 3.32:
##      :      :...alcohol <= 10.1: good (46.6/9.1)
##      :      alcohol > 10.1: normal (3.5)
## alcohol > 10.4:
## :...sulphates > 0.67:
##      :...volatile.acidity <= 0.33:
##      :      :...alcohol > 12.2: good (14.2)
##      :      :      alcohol <= 12.2:
##      :      :      :...chlorides > 0.099: normal (6.6)
##      :      :      chlorides <= 0.099:
##      :      :      :...sulphates <= 0.73: normal (20.6/6.6)
##      :      :      sulphates > 0.73: good (64.7/14.5)
##      :      volatile.acidity > 0.33:
##      :      :...fixed.acidity > 12.2: normal (13.9)
##      :      fixed.acidity <= 12.2:
##      :      :...free.sulfur.dioxide > 38: normal (12.8)
##      :      free.sulfur.dioxide <= 38:
##      :      :...residual.sugar > 3.1: good (36.1/8.4)
##      :      residual.sugar <= 3.1:
##      :      :...density > 0.99803: normal (12.7)
##      :      density <= 0.99803:
##      :      :...density <= 0.99374: good (19.4/4.2)
##      :      density > 0.99374:
##      :      :...total.sulfur.dioxide > 67: normal (10.2)
##      :      total.sulfur.dioxide <= 67:
##      :      :...fixed.acidity > 10.5: good (5.7)
##      :      fixed.acidity <= 10.5:
##      :      :...volatile.acidity > 0.55: good (25.6/8.6)
##      :      volatile.acidity <= 0.55:
##      :      :...density > 0.99569: normal (40.5/5.3)
##      :      density <= 0.99569: [S1]
## sulphates <= 0.67:
## :...chlorides > 0.108: normal (21.3/2.3)
##      chlorides <= 0.108:
##      :...pH > 3.27:
##      :      :...residual.sugar > 6.1: bad (6)
##      :      residual.sugar <= 6.1:
##      :      :...chlorides > 0.095: bad (10.5/4.3)
##      :      chlorides <= 0.095:
##      :      :...citric.acid <= 0.01:
##      :      :...volatile.acidity <= 0.48: bad (4.1/0.5)
##      :      :      volatile.acidity > 0.48:
##      :      :      :...chlorides <= 0.084: normal (13.2/3.3)

```

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##           :           chlorides > 0.084: good (15.1)
##           :           citric.acid > 0.01:
##           :           :...residual.sugar > 5.2: good (3.3)
##           :           residual.sugar <= 5.2:
##           :           :...density > 0.99514: normal (32.6)
##           :           density <= 0.99514:
##           :           :...total.sulfur.dioxide <= 9: good (6.7)
##           :           total.sulfur.dioxide > 9:
##           :           :...fixed.acidity <= 5.5: good (7.1/1.4)
##           :           fixed.acidity > 5.5: normal (34.5/4.4)
## pH <= 3.27:
## :...chlorides > 0.102: good (8.9/0.2)
## chlorides <= 0.102:
## :...sulphates <= 0.4: good (4.3)
## sulphates > 0.4:
## :...total.sulfur.dioxide > 165: good (4.3)
## total.sulfur.dioxide <= 165:
## :...total.sulfur.dioxide > 39: normal (15.2)
## total.sulfur.dioxide <= 39:
## :...citric.acid > 0.53: normal (21.3/2.3)
## citric.acid <= 0.53:
## :...residual.sugar > 3.5: good (10.3)
## residual.sugar <= 3.5:
## :...chlorides > 0.094: normal (5.7)
## chlorides <= 0.094:
## :...density > 0.99746: normal (4.4)
## density <= 0.99746: [S2]
##
## SubTree [S1]
##
## citric.acid <= 0.28: normal (11.4)
## citric.acid > 0.28: good (34.9/12.6)
##
## SubTree [S2]
##
## sulphates <= 0.53: normal (3.4)
## sulphates > 0.53:
## :...sulphates <= 0.65: good (23.5/1.4)
## sulphates > 0.65: normal (7.9/2.5)
##
## ----- Trial 7: -----
##
## Decision tree:
##
## volatile.acidity > 0.665:
## :...sulphates > 0.64:
## : :...alcohol <= 10.1: normal (22/8.1)
## : : alcohol > 10.1:
## : : :...free.sulfur.dioxide <= 10: good (14.4/2.6)
## : : free.sulfur.dioxide > 10: normal (14.5/1.5)
## : sulphates <= 0.64:
## : :...alcohol > 11.8: normal (23.3/2.4)
## : alcohol <= 11.8:
## : :...alcohol > 10.8:

```

```

## :      :...residual.sugar <= 1.9: normal (8.3)
## :      :   residual.sugar > 1.9:
## :      :   :...chlorides <= 0.055: normal (4.7)
## :      :       chlorides > 0.055: bad (48.9/9.6)
## :      alcohol <= 10.8:
## :      :...pH > 3.57: bad (5.7)
## :      :   pH <= 3.57:
## :      :   :...residual.sugar > 2.25: normal (37.2)
## :      :       residual.sugar <= 2.25:
## :      :       :...alcohol > 9.8: normal (20.8)
## :      :           alcohol <= 9.8:
## :      :           :...fixed.acidity > 8.1: bad (15.4/1.1)
## :      :               fixed.acidity <= 8.1:
## :      :               :...volatile.acidity <= 0.965: normal (26.8/5.8)
## :      :                   volatile.acidity > 0.965: bad (6/0.2)
## volatile.acidity <= 0.665:
## :...alcohol <= 9.6:
## :   :...volatile.acidity <= 0.23: bad (7/3.1)
## :   :   volatile.acidity > 0.23:
## :   :   :...density <= 0.99682:
## :   :       :...density <= 0.99678: normal (43.5/2.4)
## :   :       :   density > 0.99678: good (10.1/1.8)
## :   :       density > 0.99682:
## :   :       :...fixed.acidity <= 10.3: normal (113/5.8)
## :   :           fixed.acidity > 10.3:
## :   :           :...alcohol <= 9.55: normal (22.2/3.2)
## :   :               alcohol > 9.55: bad (6.2/0.6)
## alcohol > 9.6:
## :...sulphates <= 0.58:
## :   :...alcohol <= 9.9: normal (23.9)
## :   :   alcohol > 9.9:
## :   :   :...pH > 3.27:
## :   :       :...residual.sugar <= 1.9:
## :   :       :       :...total.sulfur.dioxide <= 21: good (16.9/4.9)
## :   :       :           :   total.sulfur.dioxide > 21: normal (15.2)
## :   :       :       residual.sugar > 1.9:
## :   :       :       :...residual.sugar <= 2.15: bad (20.3/6.7)
## :   :       :           residual.sugar > 2.15:
## :   :       :           :...chlorides <= 0.054: bad (4.7)
## :   :       :               chlorides > 0.054: normal (29.3/6.6)
## :   :       pH <= 3.27:
## :   :       :...total.sulfur.dioxide > 165: good (3.4)
## :   :           total.sulfur.dioxide <= 165:
## :   :           :...sulphates <= 0.4: good (3.4)
## :   :               sulphates > 0.4:
## :   :               :...total.sulfur.dioxide > 18: normal (21.7)
## :   :                   total.sulfur.dioxide <= 18:
## :   :                   :...citric.acid > 0.52: normal (9.5)
## :   :                       citric.acid <= 0.52:
## :   :                       :...volatile.acidity <= 0.44: good (23.3/9)
## :   :                           volatile.acidity > 0.44: normal (5.4)
## sulphates > 0.58:
## :...pH > 3.61:
## :   :...total.sulfur.dioxide <= 19: bad (10/4)

```

```

##           :   total.sulfur.dioxide > 19: normal (23.8/4.8)
## pH <= 3.61:
##           :...total.sulfur.dioxide > 56:
##             :...residual.sugar <= 2.05: good (24/8.8)
##             :   residual.sugar > 2.05: normal (86.4/8.2)
##             total.sulfur.dioxide <= 56:
##             :...alcohol > 11.5:
##               :...residual.sugar <= 2.25:
##               :   :...volatile.acidity <= 0.31: good (15.8/1.3)
##               :   :   volatile.acidity > 0.31: normal (42.3/9.3)
##               :   residual.sugar > 2.25:
##               :   :...pH > 3.47: normal (4.4/0.2)
##               :   pH <= 3.47:
##               :   :...volatile.acidity <= 0.315: normal (13.5/3.2)
##               :   volatile.acidity > 0.315:
##               :   :...total.sulfur.dioxide <= 9: normal (3.3)
##               :   total.sulfur.dioxide > 9:
##               :   :...sulphates <= 0.91: good (65.8/6.5)
##               :   sulphates > 0.91: normal (7.5/1.7)
##             alcohol <= 11.5:
##             :...citric.acid <= 0.05: normal (19.2)
##             citric.acid > 0.05:
##             :...density > 1.00005: normal (13.3)
##             density <= 1.00005:
##             :...pH <= 3.02: good (14/0.9)
##             pH > 3.02:
##             :...fixed.acidity > 11.6: good (26.9/7.4)
##             fixed.acidity <= 11.6:
##             :...citric.acid <= 0.17:
##             :...density <= 0.99512: normal (12.9)
##             :   density > 0.99512:
##             :   :...alcohol <= 10.03333: normal (2.7)
##             :   alcohol > 10.03333: good (37.6/7.4)
##             citric.acid > 0.17:
##             :...citric.acid <= 0.27: normal (34.4)
##             citric.acid > 0.27:
##             :...alcohol <= 9.7: good (8.3/0.2)
##             alcohol > 9.7: [S1]
##
## SubTree [S1]
##
## free.sulfur.dioxide > 29: good (11.9/4)
## free.sulfur.dioxide <= 29:
## :...free.sulfur.dioxide > 24: normal (14.4)
##   free.sulfur.dioxide <= 24:
##   :...density <= 0.99538: good (26.8/7.5)
##   density > 0.99538:
##   :...total.sulfur.dioxide > 46: good (21.6/8.3)
##   total.sulfur.dioxide <= 46:
##   :...density <= 0.9996: normal (107.3/18.5)
##   density > 0.9996: good (4.1)
##
## ----- Trial 8: -----
##

```

```

## Decision tree:
##
## sulphates <= 0.61:
## :...alcohol > 11.2:
## :   :...free.sulfur.dioxide <= 31: normal (133.1/29.7)
## :   :   free.sulfur.dioxide > 31: good (12.4/3.5)
## :   alcohol <= 11.2:
## :   :...pH <= 3.22: normal (75.4/5.2)
## :   :   pH > 3.22:
## :   :   :...fixed.acidity > 9.7: bad (21/8.1)
## :   :   :   fixed.acidity <= 9.7:
## :   :   :   :...total.sulfur.dioxide <= 21:
## :   :   :   :   :...free.sulfur.dioxide > 8: good (18.2/7.3)
## :   :   :   :   :   free.sulfur.dioxide <= 8:
## :   :   :   :   :   :...alcohol > 11: good (5.4/2.2)
## :   :   :   :   :   :   alcohol <= 11:
## :   :   :   :   :   :   :...citric.acid > 0.09: normal (19.5/2)
## :   :   :   :   :   :   :   citric.acid <= 0.09:
## :   :   :   :   :   :   :   :...free.sulfur.dioxide <= 3: normal (4.3)
## :   :   :   :   :   :   :   :   free.sulfur.dioxide > 3:
## :   :   :   :   :   :   :   :   :...residual.sugar <= 4.5: bad (36.9/10.6)
## :   :   :   :   :   :   :   :   :   residual.sugar > 4.5: normal (2.9)
## :   :   :   total.sulfur.dioxide > 21:
## :   :   :   :...sulphates > 0.57:
## :   :   :   :   :...volatile.acidity <= 0.915: normal (50.1)
## :   :   :   :   :   volatile.acidity > 0.915: bad (2.4)
## :   :   :   sulphates <= 0.57:
## :   :   :   :...sulphates <= 0.45: normal (12.7)
## :   :   :   :   sulphates > 0.45:
## :   :   :   :   :...total.sulfur.dioxide > 64: normal (30.3/2)
## :   :   :   :   :   total.sulfur.dioxide <= 64:
## :   :   :   :   :   :...sulphates <= 0.52:
## :   :   :   :   :   :   :...volatile.acidity <= 0.915: bad (33.8/11.1)
## :   :   :   :   :   :   :   volatile.acidity > 0.915: normal (6.9)
## :   :   :   sulphates > 0.52:
## :   :   :   :...residual.sugar <= 1.9: normal (14.9)
## :   :   :   :   residual.sugar > 1.9:
## :   :   :   :   :...residual.sugar <= 2.35: bad (23.2/8.5)
## :   :   :   :   :   residual.sugar > 2.35: normal (10.7)
## sulphates > 0.61:
## :...chlorides > 0.122:
## :   :...pH > 3.37: bad (10.7/1.6)
## :   :   pH <= 3.37:
## :   :   :...alcohol <= 8.4: bad (3.1)
## :   :   :   alcohol > 8.4: normal (32.1/7.6)
## chlorides <= 0.122:
## :...residual.sugar <= 1.5:
## :   :...volatile.acidity <= 0.575: normal (26.6/10.3)
## :   :   volatile.acidity > 0.575: bad (13.5/3.2)
## residual.sugar > 1.5:
## :...volatile.acidity > 0.735: normal (28.4/6.8)
## :   volatile.acidity <= 0.735:
## :   :...alcohol > 11.4:
## :   :   :...volatile.acidity > 0.645: good (20.9/2.2)

```

```

##      : volatile.acidity <= 0.645:
##      :      :...alcohol <= 11.5: normal (18/5.2)
##      :      alcohol > 11.5:
##      :      :...volatile.acidity > 0.59: normal (12.2/1.4)
##      :      volatile.acidity <= 0.59:
##      :      :...sulphates > 0.83:
##      :      :...total.sulfur.dioxide <= 16: normal (2.7)
##      :      :      total.sulfur.dioxide > 16: good (31.6/2.3)
##      :      sulphates <= 0.83:
##      :      :...alcohol <= 11.7: good (23.1/3.2)
##      :      alcohol > 11.7:
##      :      :...pH > 3.71: good (5.3)
##      :      pH <= 3.71:
##      :      :...total.sulfur.dioxide <= 46:
##      :      :...sulphates <= 0.7: normal (33.4/11.2)
##      :      :      sulphates > 0.7: good (34.6/7.8)
##      :      total.sulfur.dioxide > 46: [S1]
## alcohol <= 11.4:
## :...volatile.acidity > 0.4:
## :      :...citric.acid > 0.65: good (8.2/2.3)
## :      citric.acid <= 0.65:
## :      :...total.sulfur.dioxide > 54: normal (53.1)
## :      total.sulfur.dioxide <= 54:
## :      :...density > 0.99842: normal (35.4)
## :      density <= 0.99842:
## :      :...fixed.acidity <= 6.9: normal (43.3/1.7)
## :      fixed.acidity > 6.9:
## :      :...residual.sugar > 4.5: good (3.6)
## :      residual.sugar <= 4.5:
## :      :...pH > 3.51: good (7.8/0.4)
## :      pH <= 3.51: [S2]
## volatile.acidity <= 0.4:
## :...chlorides > 0.096: normal (11.7)
## chlorides <= 0.096:
## :...fixed.acidity <= 8.4:
## :      :...total.sulfur.dioxide > 50: normal (25.6)
## :      total.sulfur.dioxide <= 50:
## :      :...volatile.acidity > 0.35: good (11.2/1.2)
## :      volatile.acidity <= 0.35:
## :      :...total.sulfur.dioxide <= 15: good (3.8)
## :      total.sulfur.dioxide > 15: normal (27.6/3.3)
## fixed.acidity > 8.4:
## :...density > 1.00025: normal (6.2)
## density <= 1.00025:
## :...fixed.acidity > 14: good (5.2)
## fixed.acidity <= 14:
## :...citric.acid > 0.68: good (6.5)
## citric.acid <= 0.68:
## :...alcohol <= 10.4:
## :      :...density <= 0.99774: good (10.7/3.1)
## :      density > 0.99774: normal (26.1/4.2)
## alcohol > 10.4:
## :...alcohol > 11.2: normal (4.9)
## alcohol <= 11.2: [S3]

```

```

##
## SubTree [S1]
##
## total.sulfur.dioxide <= 83: normal (33.1/3.7)
## total.sulfur.dioxide > 83: good (7.5/1.4)
##
## SubTree [S2]
##
## free.sulfur.dioxide > 30: good (4.1)
## free.sulfur.dioxide <= 30:
## :...free.sulfur.dioxide > 20: normal (11.1)
##     free.sulfur.dioxide <= 20:
##         :...total.sulfur.dioxide <= 48: normal (48.6/11.1)
##         total.sulfur.dioxide > 48: good (6.2/0.3)
##
## SubTree [S3]
##
## residual.sugar > 2.55: good (17.5)
## residual.sugar <= 2.55:
## :...volatile.acidity > 0.38: normal (3.8)
##     volatile.acidity <= 0.38:
##         :...pH <= 3.17: good (13.8)
##         pH > 3.17:
##             :...total.sulfur.dioxide <= 20: normal (8.3)
##             total.sulfur.dioxide > 20: good (22.9/7.8)
##
## ----- Trial 9: -----
##
## Decision tree:
##
## sulphates <= 0.61:
## :...alcohol > 11.2:
## : : :...residual.sugar > 3.9:
## : : : :...citric.acid <= 0.42: bad (16.8/5.6)
## : : : : : citric.acid > 0.42: good (17.4/2.3)
## : : : residual.sugar <= 3.9:
## : : : :...total.sulfur.dioxide <= 7: bad (5.8/2.2)
## : : : : total.sulfur.dioxide > 7:
## : : : : :...fixed.acidity <= 6.5: normal (24.4)
## : : : : fixed.acidity > 6.5:
## : : : : :...sulphates <= 0.54: normal (30.3/2.2)
## : : : : sulphates > 0.54:
## : : : : :...sulphates > 0.59: normal (11.3)
## : : : : sulphates <= 0.59:
## : : : : :...citric.acid <= 0.45: good (33.1/10.1)
## : : : : : citric.acid > 0.45: normal (7.6)
## : alcohol <= 11.2:
## : :...volatile.acidity > 0.665:
## : : :...density <= 0.9948: bad (10.6/1)
## : : : density > 0.9948:
## : : : :...alcohol > 10.9: bad (22.2/8.3)
## : : : : alcohol <= 10.9:
## : : : : :...sulphates > 0.58: bad (11.5/4.5)
## : : : : sulphates <= 0.58:

```

```

## :      :      :...total.sulfur.dioxide <= 9: bad (3.9)
## :      :      total.sulfur.dioxide > 9:
## :      :      :...pH <= 3.28: normal (29.3)
## :      :      pH > 3.28:
## :      :      :...citric.acid <= 0.25: normal (84.9/9)
## :      :      citric.acid > 0.25: bad (4.7/0.1)
## : volatile.acidity <= 0.665:
## : :...total.sulfur.dioxide > 55: normal (48.9)
## :      total.sulfur.dioxide <= 55:
## :      :...total.sulfur.dioxide > 45:
## :      :...total.sulfur.dioxide <= 49: bad (19.6/6.8)
## :      :      total.sulfur.dioxide > 49: normal (13.8/1.3)
## :      total.sulfur.dioxide <= 45:
## :      :...total.sulfur.dioxide > 44: good (5.9/0.8)
## :      total.sulfur.dioxide <= 44:
## :      :...total.sulfur.dioxide > 21: normal (96.4/8.1)
## :      total.sulfur.dioxide <= 21:
## :      :...free.sulfur.dioxide > 8: good (13.2/4.6)
## :      free.sulfur.dioxide <= 8:
## :      :...alcohol > 11: good (4.7/2.1)
## :      alcohol <= 11:
## :      :...chlorides <= 0.1: normal (30.6/3.2)
## :      chlorides > 0.1: bad (10.8/3.5)
## sulphates > 0.61:
## :...alcohol > 11.5:
## :      :...free.sulfur.dioxide > 18:
## :      :      :...volatile.acidity > 0.6: normal (8.8)
## :      :      volatile.acidity <= 0.6:
## :      :      :...free.sulfur.dioxide > 27: good (24.5/6.1)
## :      :      free.sulfur.dioxide <= 27:
## :      :      :...pH <= 3.71: normal (30.8/4.9)
## :      :      pH > 3.71: good (4.2)
## :      free.sulfur.dioxide <= 18:
## :      :...volatile.acidity > 0.645: good (22.2)
## :      volatile.acidity <= 0.645:
## :      :...fixed.acidity > 9.6:
## :      :      :...residual.sugar <= 2.3: normal (9.9)
## :      :      residual.sugar > 2.3:
## :      :      :...volatile.acidity <= 0.32: normal (4.8)
## :      :      volatile.acidity > 0.32: good (32.1/11.8)
## :      fixed.acidity <= 9.6:
## :      :...pH <= 3.34: good (39.4/2.5)
## :      pH > 3.34:
## :      :...alcohol > 13.2: good (7.5)
## :      alcohol <= 13.2:
## :      :...volatile.acidity <= 0.5: normal (24.9/7.1)
## :      volatile.acidity > 0.5: good (9.2/1.3)
## alcohol <= 11.5:
## :...citric.acid <= 0.09:
## :      :...total.sulfur.dioxide <= 13: bad (8.7/0.2)
## :      total.sulfur.dioxide > 13:
## :      :...sulphates <= 1.02: normal (58.8/7.4)
## :      sulphates > 1.02: bad (2.8)
## citric.acid > 0.09:

```



```

##      :...total.sulfur.dioxide > 49:
##      :...volatile.acidity > 0.915: bad (5.6/1.2)
##      :   volatile.acidity <= 0.915:
##      :   :...alcohol <= 9.9: normal (49.7/5.9)
##      :       alcohol > 9.9:
##      :       :...alcohol <= 10.03333: good (6.2/0.7)
##      :           alcohol > 10.03333:
##      :           :...free.sulfur.dioxide <= 43: normal (64.2/6.7)
##      :               free.sulfur.dioxide > 43: good (7.1/1.1)
##      total.sulfur.dioxide <= 49:
##      :...citric.acid <= 0.17:
##      :...total.sulfur.dioxide > 36: normal (4)
##      :   total.sulfur.dioxide <= 36:
##      :   :...fixed.acidity <= 8.1: good (32.3/3.7)
##      :       fixed.acidity > 8.1: normal (2.5)
##      citric.acid > 0.17:
##      :...citric.acid <= 0.27: normal (30.2)
##      :       citric.acid > 0.27:
##      :       :...sulphates <= 0.63: normal (15.2/2.4)
##      :           sulphates > 0.63:
##      :           :...chlorides <= 0.058: good (25.3/5.7)
##      :               chlorides > 0.058:
##      :               :...free.sulfur.dioxide > 24: normal (11.1)
##      :                   free.sulfur.dioxide <= 24:
##      :                   :...pH <= 3.15:
##      :                       :...free.sulfur.dioxide > 19: good (8)
##      :                           free.sulfur.dioxide <= 19: [S1]
##      :                           pH > 3.15:
##      :                           :...citric.acid <= 0.32: good (13.5/1.7)
##      :                               citric.acid > 0.32:
##      :                               :...chlorides <= 0.068: normal (26.7)
##      :                                   chlorides > 0.068:
##      :                                   :...residual.sugar > 6.7: good (3)
##      :                                       residual.sugar <= 6.7: [S2]
##
## SubTree [S1]
##
## free.sulfur.dioxide > 12: normal (9.3/1.3)
## free.sulfur.dioxide <= 12:
## :...density <= 0.9979: good (22.9/2.5)
##     density > 0.9979:
##     :...total.sulfur.dioxide <= 22: normal (9.7)
##         total.sulfur.dioxide > 22: good (20/5.3)
##
## SubTree [S2]
##
## chlorides > 0.085: normal (23.5/0.6)
## chlorides <= 0.085:
## :...alcohol <= 11.1: normal (34.1/11.7)
##     alcohol > 11.1: good (7.7/0.1)
##
##
## Evaluation on training data (1279 cases):
##

```

```
## Trial      Decision Tree
## -----
##      Size      Errors
##
##      0      62    76( 5.9%)
##      1      46   171(13.4%)
##      2      64   202(15.8%)
##      3      54   179(14.0%)
##      4      59   160(12.5%)
##      5      69   162(12.7%)
##      6      68   145(11.3%)
##      7      57   200(15.6%)
##      8      62   175(13.7%)
##      9      62   166(13.0%)
## boost      2( 0.2%)    <<
##
##
##      (a)   (b)   (c)   <-classified as
##      ----  ----  ----
##      48           2    (a): class bad
##           179         (b): class good
##           1050        (c): class normal
##
##
## Attribute usage:
##
## 100.00% volatile.acidity
## 100.00% sulphates
## 100.00% alcohol
## 99.84% residual.sugar
## 99.77% total.sulfur.dioxide
## 99.06% chlorides
## 98.59% free.sulfur.dioxide
## 97.26% fixed.acidity
## 97.26% pH
## 87.88% citric.acid
## 87.88% density
##
##
## Time: 0.2 secs
```

```
WineData_boost10_predict <- predict(WineData_boost10, WineData_test)
CrossTable(WineData_test$quality, WineData_boost10_predict, prop.chisq = FALSE, prop.c = FALSE, prop.r = FALSE)
```

```
##
##
##      Cell Contents
## |-----|
## |                      N |
## |      N / Table Total |
## |-----|
##
##
## Total Observations in Table: 320
##
```

```
##
##           | Predicted Class
## Actual Class |      bad |      good |      normal | Row Total |
## -----|-----|-----|-----|-----|
##      bad |      1 |      0 |      12 |      13 |
##           |    0.003 |    0.000 |    0.037 |           |
## -----|-----|-----|-----|-----|
##      good |      0 |     24 |     14 |     38 |
##           |    0.000 |    0.075 |    0.044 |           |
## -----|-----|-----|-----|-----|
##     normal |      1 |      9 |     259 |     269 |
##           |    0.003 |    0.028 |    0.809 |           |
## -----|-----|-----|-----|-----|
## Column Total |      2 |     33 |     285 |     320 |
## -----|-----|-----|-----|-----|
##
##
```

```
confusionMatrix(WineData_test$quality, WineData_boost10_predict)
```

```
## Confusion Matrix and Statistics
```

```
##
```

```
##           Reference
```

```
## Prediction bad good normal
```

```
##      bad      1      0      12
```

```
##      good      0     24     14
```

```
##      normal      1      9     259
```

```
##
```

```
## Overall Statistics
```

```
##
```

```
##           Accuracy : 0.8875
```

```
##           95% CI : (0.8477, 0.92)
```

```
##      No Information Rate : 0.8906
```

```
##      P-Value [Acc > NIR] : 0.6142
```

```
##
```

```
##           Kappa : 0.5289
```

```
##      McNemar's Test P-Value : NA
```

```
##
```

```
## Statistics by Class:
```

```
##
```

```
##           Class: bad Class: good Class: normal
```

```
## Sensitivity      0.500000      0.7273      0.9088
```

```
## Specificity      0.962264      0.9512      0.7143
```

```
## Pos Pred Value    0.076923      0.6316      0.9628
```

```
## Neg Pred Value    0.996743      0.9681      0.4902
```

```
## Prevalence        0.006250      0.1031      0.8906
```

```
## Detection Rate    0.003125      0.0750      0.8094
```

```
## Detection Prevalence 0.040625      0.1187      0.8406
```

```
## Balanced Accuracy  0.731132      0.8392      0.8115
```