Practice 6

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```r
#Importing Libraries
library(psych)
```

```
## Warning: package 'psych' was built under R version 4.0.2
```

```r
#Importing student data
student_mat <- read.csv("student-mat.csv",sep=";",header=TRUE)

#Viewing at the head and the structure of the data
head(student_mat)
```

```
##   school sex age address famsize Pstatus Medu Fedu    Mjob     Fjob     reason
## 1     GP   F  18       U     GT3       A    4    4 at_home  teacher     course
## 2     GP   F  17       U     GT3       T    1    1 at_home    other     course
## 3     GP   F  15       U     LE3       T    1    1 at_home    other      other
## 4     GP   F  15       U     GT3       T    4    2  health services       home
## 5     GP   F  16       U     GT3       T    3    3   other    other       home
## 6     GP   M  16       U     LE3       T    4    3 services    other reputation
##   guardian traveltime studytime failures schoolsup famsup paid activities
## 1   mother          2         2        0       yes     no   no         no
## 2   father          1         2        0        no    yes   no         no
## 3   mother          1         2        3       yes     no  yes         no
## 4   mother          1         3        0        no    yes  yes        yes
## 5   father          1         2        0        no    yes  yes         no
## 6   mother          1         2        0        no    yes  yes        yes
##   nursery higher internet romantic famrel freetime goout Dalc Walc health
## 1     yes    yes       no       no      4        3     4    1    1      3
## 2      no    yes      yes       no      5        3     3    1    1      3
## 3     yes    yes      yes       no      4        3     2    2    3      3
## 4     yes    yes      yes      yes      3        2     2    1    1      5
## 5     yes    yes       no       no      4        3     2    1    2      5
## 6     yes    yes      yes       no      5        4     2    1    2      5
##   absences G1 G2 G3
## 1        6  5  6  6
## 2        4  5  5  6
## 3       10  7  8 10
## 4        2 15 14 15
## 5        4  6 10 10
## 6       10 15 15 15
```

```r
str(student_mat)
```

```
## 'data.frame':    395 obs. of  33 variables:
##  $ school    : chr  "GP" "GP" "GP" "GP" ...
##  $ sex       : chr  "F" "F" "F" "F" ...
##  $ age       : int  18 17 15 15 16 16 16 17 15 15 ...
##  $ address   : chr  "U" "U" "U" "U" ...
##  $ famsize   : chr  "GT3" "GT3" "LE3" "GT3" ...
##  $ Pstatus   : chr  "A" "T" "T" "T" ...
##  $ Medu      : int  4 1 1 4 3 4 2 4 3 3 ...
##  $ Fedu      : int  4 1 1 2 3 3 2 4 2 4 ...
##  $ Mjob      : chr  "at_home" "at_home" "at_home" "health" ...
##  $ Fjob      : chr  "teacher" "other" "other" "services" ...
##  $ reason    : chr  "course" "course" "other" "home" ...
##  $ guardian  : chr  "mother" "father" "mother" "mother" ...
##  $ traveltime: int  2 1 1 1 1 1 1 2 1 1 ...
##  $ studytime : int  2 2 2 3 2 2 2 2 2 2 ...
##  $ failures  : int  0 0 3 0 0 0 0 0 0 0 ...
##  $ schoolsup : chr  "yes" "no" "yes" "no" ...
##  $ famsup    : chr  "no" "yes" "no" "yes" ...
##  $ paid      : chr  "no" "no" "yes" "yes" ...
##  $ activities: chr  "no" "no" "no" "yes" ...
##  $ nursery   : chr  "yes" "no" "yes" "yes" ...
##  $ higher    : chr  "yes" "yes" "yes" "yes" ...
##  $ internet  : chr  "no" "yes" "yes" "yes" ...
##  $ romantic  : chr  "no" "no" "no" "yes" ...
##  $ famrel    : int  4 5 4 3 4 5 4 4 4 5 ...
##  $ freetime  : int  3 3 3 2 3 4 4 1 2 5 ...
##  $ goout     : int  4 3 2 2 2 2 4 4 2 1 ...
##  $ Dalc      : int  1 1 2 1 1 1 1 1 1 1 ...
##  $ Walc      : int  1 1 3 1 2 2 1 1 1 1 ...
##  $ health    : int  3 3 3 5 5 5 3 1 1 5 ...
##  $ absences  : int  6 4 10 2 4 10 0 6 0 0 ...
##  $ G1        : int  5 5 7 15 6 15 12 6 16 14 ...
##  $ G2        : int  6 5 8 14 10 15 12 5 18 15 ...
##  $ G3        : int  6 6 10 15 10 15 11 6 19 15 ...
```

```r
#Plotting the histogram and the correlation between different features
pairs.panels(student_mat[c("age", "absences", "G1", "G2", "G3")])
```
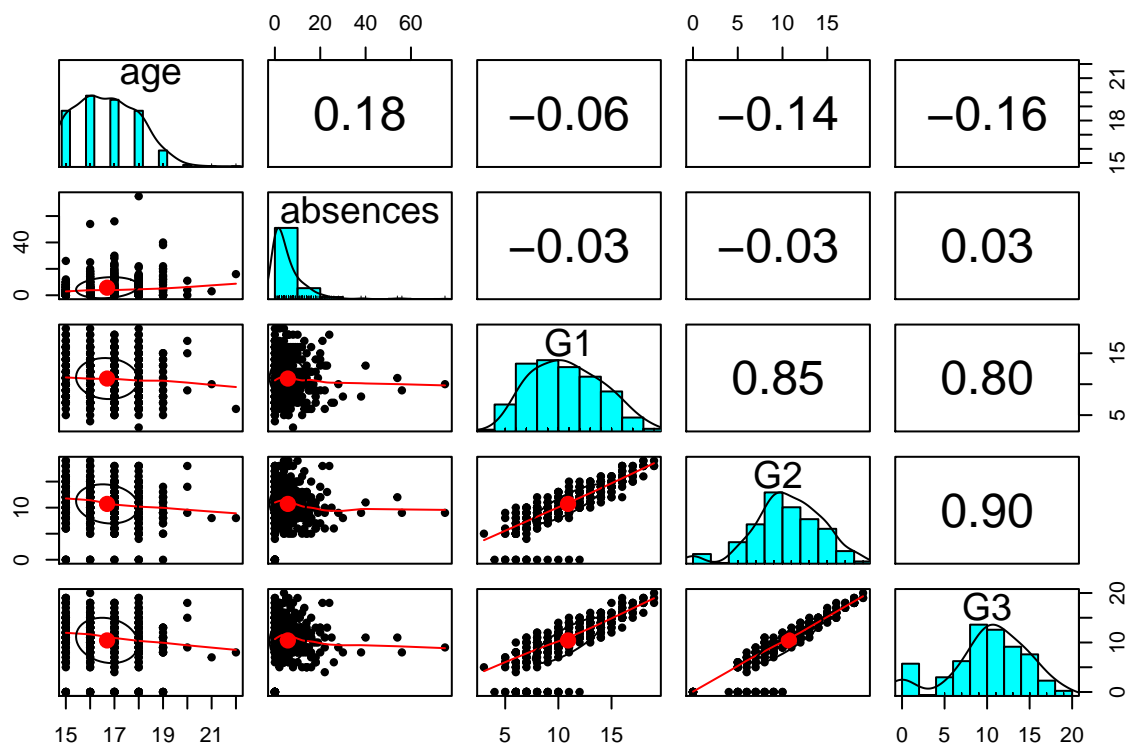
```
#Summaring the student data
summary(student_mat)
```

```
##     school              sex                 age            address
##  Length:395         Length:395          Min.   :15.0    Length:395
##  Class :character   Class :character    1st Qu.:16.0    Class :character
##  Mode  :character   Mode  :character    Median :17.0    Mode  :character
##                                         Mean   :16.7
##                                         3rd Qu.:18.0
##                                         Max.   :22.0
##     famsize             Pstatus             Medu            Fedu
##  Length:395         Length:395          Min.   :0.000   Min.   :0.000
##  Class :character   Class :character    1st Qu.:2.000   1st Qu.:2.000
##  Mode  :character   Mode  :character    Median :3.000   Median :2.000
##                                         Mean   :2.749   Mean   :2.522
##                                         3rd Qu.:4.000   3rd Qu.:3.000
##                                         Max.   :4.000   Max.   :4.000
##     Mjob                Fjob                reason             guardian
##  Length:395         Length:395          Length:395         Length:395
##  Class :character   Class :character    Class :character   Class :character
##  Mode  :character   Mode  :character    Mode  :character   Mode  :character
##
##
##
##    traveltime       studytime         failures         schoolsup
##  Min.   :1.000   Min.   :1.000    Min.   :0.0000    Length:395
```

3

```
##  1st Qu.:1.000   1st Qu.:1.000   1st Qu.:0.0000   Class :character
##  Median :1.000   Median :2.000   Median :0.0000   Mode  :character
##  Mean   :1.448   Mean   :2.035   Mean   :0.3342
##  3rd Qu.:2.000   3rd Qu.:2.000   3rd Qu.:0.0000
##  Max.   :4.000   Max.   :4.000   Max.   :3.0000
##     famsup             paid            activities          nursery
##  Length:395         Length:395         Length:395         Length:395
##  Class :character   Class :character   Class :character   Class :character
##  Mode  :character   Mode  :character   Mode  :character   Mode  :character
##
##
##
##     higher            internet          romantic            famrel
##  Length:395         Length:395         Length:395         Min.   :1.000
##  Class :character   Class :character   Class :character   1st Qu.:4.000
##  Mode  :character   Mode  :character   Mode  :character   Median :4.000
##                                                           Mean   :3.944
##                                                           3rd Qu.:5.000
##                                                           Max.   :5.000
##     freetime           goout            Dalc               Walc
##  Min.   :1.000   Min.   :1.000   Min.   :1.000   Min.   :1.000
##  1st Qu.:3.000   1st Qu.:2.000   1st Qu.:1.000   1st Qu.:1.000
##  Median :3.000   Median :3.000   Median :1.000   Median :2.000
##  Mean   :3.235   Mean   :3.109   Mean   :1.481   Mean   :2.291
##  3rd Qu.:4.000   3rd Qu.:4.000   3rd Qu.:2.000   3rd Qu.:3.000
##  Max.   :5.000   Max.   :5.000   Max.   :5.000   Max.   :5.000
##     health           absences            G1                G2
##  Min.   :1.000   Min.   : 0.000   Min.   : 3.00   Min.   : 0.00
##  1st Qu.:3.000   1st Qu.: 0.000   1st Qu.: 8.00   1st Qu.: 9.00
##  Median :4.000   Median : 4.000   Median :11.00   Median :11.00
##  Mean   :3.554   Mean   : 5.709   Mean   :10.91   Mean   :10.71
##  3rd Qu.:5.000   3rd Qu.: 8.000   3rd Qu.:13.00   3rd Qu.:13.00
##  Max.   :5.000   Max.   :75.000   Max.   :19.00   Max.   :19.00
##       G3
##  Min.   : 0.00
##  1st Qu.: 8.00
##  Median :11.00
##  Mean   :10.42
##  3rd Qu.:14.00
##  Max.   :20.00
```

```r
#Selcting relevant features
selected_features <- student_mat[c("school", "sex", "age", "famsize", "Mjob", "Fjob", "studytime", "acti

#Creating factors of v=binary values
selected_features$school <- as.factor(selected_features$school)
selected_features$sex <- as.factor(selected_features$sex)
selected_features$famsize <- as.factor(selected_features$famsize)
selected_features$activities  <- as.factor(selected_features$activit)

#Running multiple regression for selected features
pred <- lm(G3~school+sex+age+famsize+Mjob+Fjob+studytime+activities+famrel+absences+G1+G2, data = select

#We observed the R-Squared values as 0.8388 and the p value is quite low
```

```
summary(pred)
```

```
##
## Call:
## lm(formula = G3 ~ school + sex + age + famsize + Mjob + Fjob +
##     studytime + activities + famrel + absences + G1 + G2, data = selected_features)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.6016 -0.4910  0.2957  1.0726  3.8492
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)   0.720883   1.573550   0.458 0.647127
## schoolMS      0.520860   0.332152   1.568 0.117690
## sexM          0.146997   0.210162   0.699 0.484706
## age          -0.251264   0.085071  -2.954 0.003339 **
## famsizeLE3    0.020418   0.214102   0.095 0.924076
## Mjobhealth   -0.012931   0.422871  -0.031 0.975621
## Mjobother     0.002835   0.301081   0.009 0.992493
## Mjobservices  0.122875   0.317790   0.387 0.699230
## Mjobteacher   0.101688   0.369876   0.275 0.783525
## Fjobhealth    0.495598   0.635701   0.780 0.436111
## Fjobother     0.186309   0.452396   0.412 0.680700
## Fjobservices -0.257288   0.470101  -0.547 0.584494
## Fjobteacher   0.025216   0.565988   0.045 0.964487
## studytime    -0.100208   0.125225  -0.800 0.424089
## activitiesyes -0.313166   0.195497  -1.602 0.110019
## famrel        0.381599   0.108144   3.529 0.000469 ***
## absences      0.046591   0.012426   3.749 0.000205 ***
## G1            0.159328   0.057477   2.772 0.005848 **
## G2            0.980600   0.050076  19.582  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.883 on 376 degrees of freedom
## Multiple R-squared:  0.8388, Adjusted R-squared:  0.8311
## F-statistic: 108.7 on 18 and 376 DF,  p-value: < 2.2e-16
```

```
#Using backward elimination method to remove irrelevant features
step(pred, direction = "backward")
```

```
## Start:  AIC=518.47
## G3 ~ school + sex + age + famsize + Mjob + Fjob + studytime +
##     activities + famrel + absences + G1 + G2
##
##             Df Sum of Sq    RSS    AIC
## - Mjob       4      1.15 1334.3 510.81
## - Fjob       4     16.70 1349.8 515.39
## - famsize    1      0.03 1333.2 516.48
## - sex        1      1.73 1334.8 516.99
## - studytime  1      2.27 1335.4 517.14
```

```
## <none>                       1333.1 518.47
## - school      1        8.72 1341.8 519.05
## - activities  1        9.10 1342.2 519.16
## - G1          1       27.24 1360.4 524.46
## - age         1       30.93 1364.0 525.53
## - famrel      1       44.15 1377.3 529.34
## - absences    1       49.84 1383.0 530.97
## - G2          1     1359.56 2692.7 794.16
##
## Step:  AIC=510.81
## G3 ~ school + sex + age + famsize + Fjob + studytime + activities +
##     famrel + absences + G1 + G2
##
##             Df Sum of Sq    RSS    AIC
## - Fjob       4     15.69 1350.0 507.43
## - famsize    1      0.08 1334.3 508.84
## - sex        1      2.05 1336.3 509.42
## - studytime  1      2.28 1336.5 509.49
## <none>                   1334.3 510.81
## - school     1      8.44 1342.7 511.30
## - activities 1      8.75 1343.0 511.40
## - G1         1     28.31 1362.6 517.11
## - age        1     31.18 1365.5 517.94
## - famrel     1     45.07 1379.3 521.94
## - absences   1     50.86 1385.1 523.59
## - G2         1   1379.31 2713.6 789.22
##
## Step:  AIC=507.43
## G3 ~ school + sex + age + famsize + studytime + activities +
##     famrel + absences + G1 + G2
##
##             Df Sum of Sq    RSS    AIC
## - famsize    1      0.17 1350.1 505.48
## - studytime  1      1.89 1351.8 505.98
## - sex        1      2.10 1352.1 506.05
## - school     1      6.13 1356.1 507.22
## <none>                   1350.0 507.43
## - activities 1     10.96 1360.9 508.63
## - G1         1     31.31 1381.3 514.49
## - age        1     33.66 1383.6 515.16
## - famrel     1     43.72 1393.7 518.02
## - absences   1     50.57 1400.5 519.96
## - G2         1   1399.43 2749.4 786.40
##
## Step:  AIC=505.48
## G3 ~ school + sex + age + studytime + activities + famrel + absences +
##     G1 + G2
##
##             Df Sum of Sq    RSS    AIC
## - studytime  1      1.95 1352.1 504.05
## - sex        1      2.19 1352.3 504.12
## - school     1      6.26 1356.4 505.31
## <none>                   1350.1 505.48
## - activities 1     10.95 1361.1 506.67
```

```
## - G1          1     31.33 1381.5 512.55
## - age         1     33.57 1383.7 513.18
## - famrel      1     43.62 1393.8 516.04
## - absences    1     50.87 1401.0 518.09
## - G2          1   1403.37 2753.5 784.99
##
## Step:  AIC=504.05
## G3 ~ school + sex + age + activities + famrel + absences + G1 +
##     G2
##
##             Df Sum of Sq    RSS    AIC
## - sex        1      4.38 1356.5 503.33
## <none>                    1352.1 504.05
## - school     1      7.11 1359.2 504.13
## - activities 1     12.16 1364.2 505.59
## - G1         1     30.17 1382.3 510.77
## - age        1     34.77 1386.9 512.08
## - famrel     1     42.92 1395.0 514.40
## - absences   1     53.51 1405.6 517.39
## - G2         1   1402.16 2754.2 783.09
##
## Step:  AIC=503.33
## G3 ~ school + age + activities + famrel + absences + G1 + G2
##
##             Df Sum of Sq    RSS    AIC
## <none>                    1356.5 503.33
## - school     1      7.11 1363.6 503.40
## - activities 1     10.95 1367.4 504.51
## - G1         1     30.66 1387.1 510.16
## - age        1     34.80 1391.3 511.34
## - famrel     1     44.51 1401.0 514.08
## - absences   1     51.90 1408.4 516.16
## - G2         1   1407.40 2763.9 782.47


##
## Call:
## lm(formula = G3 ~ school + age + activities + famrel + absences +
##     G1 + G2, data = selected_features)
##
## Coefficients:
##   (Intercept)        schoolMS            age  activitiesyes         famrel
##       0.94171         0.46157       -0.26347       -0.33683        0.37837
##      absences              G1             G2
##       0.04687         0.16214        0.97643
```

```r
#Running multiple regression for the newly selected features
new_pred <- lm(G3~age+activities+famrel+absences+G1+G2, data = selected_features)

#After removing the irrelevant feature the R-Squared value is 0.8351, which also as similar to the prev
summary(new_pred)
```

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

```
## lm(formula = G3 ~ age + activities + famrel + absences + G1 +
##     G2, data = selected_features)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -8.8823 -0.4475  0.2760  1.0104  3.9410
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)    0.28769    1.38534   0.208 0.835597
## age           -0.21654    0.07695  -2.814 0.005139 **
## activitiesyes -0.35893    0.19015  -1.888 0.059816 .
## famrel         0.36624    0.10598   3.456 0.000610 ***
## absences       0.04384    0.01201   3.651 0.000297 ***
## G1             0.16158    0.05489   2.944 0.003436 **
## G2             0.97705    0.04879  20.025  < 2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 1.875 on 388 degrees of freedom
## Multiple R-squared:  0.8351, Adjusted R-squared:  0.8326
## F-statistic: 327.5 on 6 and 388 DF,  p-value: < 2.2e-16
```

```r
#Taking the Residual standard error of the above model
rse <- 1.875

#Choosing the random student from the dataset
sample_student <- student_mat[302,]
sample_student
```

```
##     school sex age address famsize Pstatus Medu Fedu  Mjob    Fjob reason
## 302     GP   M  17       U     LE3       T    4    4 other teacher   home
##     guardian traveltime studytime failures schoolsup famsup paid activities
## 302   father          2         1        0        no     no  yes         no
##     nursery higher internet romantic famrel freetime goout Dalc Walc health
## 302     yes    yes      yes       no      4        1     1    2    2      5
##     absences G1 G2 G3
## 302        0 11 11 10
```

```r
#Predicting the output for the test data
pred.sample_student <- predict(new_pred, sample_student)

#Calculating the lower boundary for the 95% confidence interval
lower.ci <- unname(pred.sample_student - (1.96 * rse))
lower.ci
```

```
## [1] 6.921412
```

```r
#Calculating the upper boundary for the 95% confidence interval
upper.ci <- unname(pred.sample_student + (1.96 * rse))
upper.ci
```

```
## [1] 14.27141
```

```
#Calculating rmse for the multi-regression model
model <- lm(G3~., data = student_mat)

#Using residual function for getting the error values of the model
rmse <- sqrt(mean(model$residuals^2))
rmse
```

```
## [1] 1.796979
```

```
#Creating a new column PASS/FAIL (P/F) for the student data
student_mat_PF <- student_mat
student_mat_PF$PF <- ifelse(student_mat_PF$G3 < 10, "F", "P")

#Converting the categorical variable to dummy code
student_mat_PF$PF <- as.factor(student_mat_PF$PF)

#Viewing at the head of the data
head(student_mat_PF)
```

```
##   school sex age address famsize Pstatus Medu Fedu     Mjob     Fjob     reason
## 1     GP   F  18       U     GT3       A    4    4  at_home  teacher     course
## 2     GP   F  17       U     GT3       T    1    1  at_home    other     course
## 3     GP   F  15       U     LE3       T    1    1  at_home    other      other
## 4     GP   F  15       U     GT3       T    4    2   health services       home
## 5     GP   F  16       U     GT3       T    3    3    other    other       home
## 6     GP   M  16       U     LE3       T    4    3 services    other reputation
##   guardian traveltime studytime failures schoolsup famsup paid activities
## 1   mother          2         2        0       yes     no   no         no
## 2   father          1         2        0        no    yes   no         no
## 3   mother          1         2        3       yes     no  yes         no
## 4   mother          1         3        0        no    yes  yes        yes
## 5   father          1         2        0        no    yes  yes         no
## 6   mother          1         2        0        no    yes  yes        yes
##   nursery higher internet romantic famrel freetime goout Dalc Walc health
## 1     yes    yes       no       no      4        3     4    1    1      3
## 2      no    yes      yes       no      5        3     3    1    1      3
## 3     yes    yes      yes       no      4        3     2    2    3      3
## 4     yes    yes      yes      yes      3        2     2    1    1      5
## 5     yes    yes       no       no      4        3     2    1    2      5
## 6     yes    yes      yes       no      5        4     2    1    2      5
##   absences G1 G2 G3 PF
## 1        6  5  6  6  F
## 2        4  5  5  6  F
## 3       10  7  8 10  P
## 4        2 15 14 15  P
## 5        4  6 10 10  P
## 6       10 15 15 15  P
```

```
#Calculating the PASS and FAIL values
table(student_mat_PF$PF)
```

```
##
```

```
##   F   P
## 130 265
```

```
#Testing binomial logistic regression for selected features
pred.glm <- glm(PF~school+sex+age+famsize+Mjob+Fjob+studytime+activities+famrel+absences+G1+G2, data=stu
```

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

```
#We observe the AIC value usinf summary fuction
summary(pred.glm)
```

```
##
## Call:
## glm(formula = PF ~ school + sex + age + famsize + Mjob + Fjob +
##     studytime + activities + famrel + absences + G1 + G2, family = "binomial",
##     data = student_mat_PF)
##
## Deviance Residuals:
##     Min       1Q   Median       3Q      Max
## -3.4942  -0.0092   0.0002   0.0338   2.3012
##
## Coefficients:
##                Estimate Std. Error z value Pr(>|z|)
## (Intercept)   -10.68089    5.42565  -1.969 0.049000 *
## schoolMS        3.41288    1.45789   2.341 0.019233 *
## sexM           -0.98766    0.68975  -1.432 0.152168
## age            -1.16404    0.32028  -3.634 0.000279 ***
## famsizeLE3     -1.10882    0.75818  -1.462 0.143607
## Mjobhealth     -2.67532    1.41252  -1.894 0.058225 .
## Mjobother      -3.08060    1.03992  -2.962 0.003053 **
## Mjobservices   -0.96638    1.01416  -0.953 0.340646
## Mjobteacher    -1.90197    1.18206  -1.609 0.107611
## Fjobhealth     -0.32848    1.98177  -0.166 0.868352
## Fjobother       3.72031    1.27637   2.915 0.003560 **
## Fjobservices    0.36558    1.26850   0.288 0.773197
## Fjobteacher     2.36019    2.01740   1.170 0.242035
## studytime      -1.86871    0.53768  -3.475 0.000510 ***
## activitiesyes  -0.59749    0.60408  -0.989 0.322621
## famrel          0.98744    0.43357   2.277 0.022759 *
## absences       -0.01408    0.03377  -0.417 0.676700
## G1              0.51450    0.23375   2.201 0.027728 *
## G2              2.83396    0.50467   5.615 1.96e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 500.504  on 394  degrees of freedom
## Residual deviance:  86.778  on 376  degrees of freedom
## AIC: 124.78
##
## Number of Fisher Scoring iterations: 9
```

```r
#Using backward elimination method to remove non-significant features
step(pred.glm, direction="backward")
```

```
## Start:  AIC=124.78
## PF ~ school + sex + age + famsize + Mjob + Fjob + studytime +
##     activities + famrel + absences + G1 + G2
```

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

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

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

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

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

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

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

```
##                 Df Deviance    AIC
## - absences       1   86.960 122.96
## - activities     1   87.772 123.77
## <none>               86.778 124.78
## - sex            1   88.899 124.90
## - famsize        1   89.053 125.05
## - G1             1   92.187 128.19
## - school         1   93.170 129.17
## - famrel         1   93.447 129.45
## - Mjob           4   99.991 129.99
## - studytime      1  102.367 138.37
## - age            1  104.950 140.95
## - Fjob           4  113.497 143.50
## - G2             1  215.935 251.94
```

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

```
##
## Step:  AIC=122.96
## PF ~ school + sex + age + famsize + Mjob + Fjob + studytime +
##     activities + famrel + G1 + G2
```

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

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

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

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

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

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

```
##                 Df Deviance    AIC
## - activities   1    87.995 122.00
## <none>              86.960 122.96
## - sex          1    89.026 123.03
## - famsize      1    90.109 124.11
## - G1           1    92.213 126.21
## - famrel       1    93.612 127.61
## - school       1    94.300 128.30
## - Mjob         4   100.997 129.00
## - studytime    1   102.612 136.61
## - age          1   106.365 140.37
## - Fjob         4   114.332 142.33
## - G2           1   218.624 252.62


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


##
## Step:  AIC=121.99
## PF ~ school + sex + age + famsize + Mjob + Fjob + studytime +
##     famrel + G1 + G2


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

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

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

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

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


##                 Df Deviance    AIC
## - sex          1    89.941 121.94
## <none>              87.995 122.00
## - famsize      1    91.391 123.39
## - G1           1    92.985 124.98
## - famrel       1    94.134 126.13
## - Mjob         4   102.108 128.11
## - school       1    96.839 128.84
## - studytime    1   103.962 135.96
## - age          1   107.135 139.13
## - Fjob         4   115.591 141.59
## - G2           1   219.154 251.15


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


##
## Step:  AIC=121.94
## PF ~ school + age + famsize + Mjob + Fjob + studytime + famrel +
##     G1 + G2


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

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

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

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


##             Df Deviance    AIC
## <none>          89.941 121.94
## - famsize    1   92.513 122.51
## - G1         1   94.280 124.28
## - famrel     1   96.614 126.61
## - Mjob       4  103.988 127.99
## - school     1   98.102 128.10
## - studytime  1  104.059 134.06
## - age        1  108.217 138.22
## - Fjob       4  116.124 140.12
## - G2         1  219.216 249.22


##
## Call:  glm(formula = PF ~ school + age + famsize + Mjob + Fjob + studytime +
##     famrel + G1 + G2, family = "binomial", data = student_mat_PF)
##
## Coefficients:
##   (Intercept)       schoolMS           age     famsizeLE3     Mjobhealth
##      -12.0068         3.5202       -1.1288        -1.0265        -3.1511
##     Mjobother    Mjobservices    Mjobteacher    Fjobhealth      Fjobother
##       -3.0336        -1.1009        -2.3292         0.3005         3.8748
## Fjobservices     Fjobteacher      studytime        famrel             G1
##        0.6764          2.9953       -1.6061         1.0270         0.4373
##           G2
##        2.8002
##
## Degrees of Freedom: 394 Total (i.e. Null);  379 Residual
## Null Deviance:        500.5
## Residual Deviance: 89.94    AIC: 121.9
```

```
#Prediction of new features
new_pred.glm <- glm(PF~age+activities+famrel+absences+G1+G2, data=student_mat_PF, family="binomial")

#Looking at the AIC value of the new prediction
summary(new_pred.glm)
```

```
##
## Call:
## glm(formula = PF ~ age + activities + famrel + absences + G1 +
##     G2, family = "binomial", data = student_mat_PF)
##
## Deviance Residuals:
##     Min        1Q     Median        3Q        Max
## -2.68903  -0.03939    0.00562   0.12715    2.33010
##
## Coefficients:
```

13

```
##                  Estimate Std. Error z value Pr(>|z|)
## (Intercept)     -13.86299    3.93632  -3.522 0.000429 ***
## age              -0.42550    0.18763  -2.268 0.023346 *
## activitiesyes    -0.78714    0.46024  -1.710 0.087214 .
## famrel            0.72166    0.29446   2.451 0.014255 *
## absences         -0.02577    0.02352  -1.096 0.273066
## G1                0.29047    0.16061   1.809 0.070523 .
## G2                1.75982    0.28146   6.252 4.04e-10 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## (Dispersion parameter for binomial family taken to be 1)
##
##     Null deviance: 500.50  on 394  degrees of freedom
## Residual deviance: 131.67  on 388  degrees of freedom
## AIC: 145.67
##
## Number of Fisher Scoring iterations: 8
```

```r
#Importing libraries for the confusionMatrix
library(caret)
```

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

```
## Loading required package: ggplot2
```

```
##
## Attaching package: 'ggplot2'
```

```
## The following objects are masked from 'package:psych':
##
##     %+%, alpha
```

```r
library(e1071)
```

```r
#Calculating accuracy of the model usinf confusionMatrix
predict.glm <- round(predict(new_pred.glm, newdata= student_mat_PF, type="response"),0)
student_mat_PF$predict.glm <- unname(predict.glm)
student_mat_PF$PF <- as.numeric(ifelse(student_mat_PF$PF == "F", 0, 1))
confusionMatrix(table(student_mat_PF$predict.glm, student_mat_PF$PF))
```

```
## Confusion Matrix and Statistics
##
##
##       0   1
##   0 114  13
##   1  16 252
##
##                Accuracy : 0.9266
##                  95% CI : (0.8963, 0.9503)
##     No Information Rate : 0.6709
##     P-Value [Acc > NIR] : <2e-16
```

```
##
##                  Kappa : 0.8328
##
##   Mcnemar's Test P-Value : 0.7103
##
##             Sensitivity : 0.8769
##             Specificity : 0.9509
##          Pos Pred Value : 0.8976
##          Neg Pred Value : 0.9403
##              Prevalence : 0.3291
##          Detection Rate : 0.2886
##    Detection Prevalence : 0.3215
##       Balanced Accuracy : 0.9139
##
##          'Positive' Class : 0
##
```

```r
#Installing packages
library(rpart)
library(rpart.plot)
```

```
## Warning: package 'rpart.plot' was built under R version 4.0.2
```

```r
library(RWeka)
library(partykit)
```

```
## Loading required package: grid
```

```
## Loading required package: libcoin
```

```
## Loading required package: mvtnorm
```

```r
#Importing wine data
wine <- read.csv("whitewines.csv")

#Viewing at the structure of the wine data
str(wine)
```

```
## 'data.frame':    4898 obs. of  12 variables:
##  $ fixed.acidity       : num  7 6.3 8.1 7.2 7.2 8.1 6.2 7 6.3 8.1 ...
##  $ volatile.acidity    : num  0.27 0.3 0.28 0.23 0.23 0.28 0.32 0.27 0.3 0.22 ...
##  $ citric.acid         : num  0.36 0.34 0.4 0.32 0.32 0.4 0.16 0.36 0.34 0.43 ...
##  $ residual.sugar      : num  20.7 1.6 6.9 8.5 8.5 6.9 7 20.7 1.6 1.5 ...
##  $ chlorides           : num  0.045 0.049 0.05 0.058 0.058 0.05 0.045 0.045 0.049 0.044 ...
##  $ free.sulfur.dioxide : num  45 14 30 47 47 30 30 45 14 28 ...
##  $ total.sulfur.dioxide: num  170 132 97 186 186 97 136 170 132 129 ...
##  $ density             : num  1.001 0.994 0.995 0.996 0.996 ...
##  $ pH                  : num  3 3.3 3.26 3.19 3.19 3.26 3.18 3 3.3 3.22 ...
##  $ sulphates           : num  0.45 0.49 0.44 0.4 0.4 0.44 0.47 0.45 0.49 0.45 ...
##  $ alcohol             : num  8.8 9.5 10.1 9.9 9.9 10.1 9.6 8.8 9.5 11 ...
##  $ quality             : int  6 6 6 6 6 6 6 6 6 6 ...
```

```
#Plotting histogram of the wine data
hist(wine$quality)
```

Histogram of wine$quality


```
#Creating training and testing dataset of the wine data
wine_train <- wine[1:3750, ]
wine_test <- wine[3751:4898, ]

#Creating a classification model using rpart
m.rpart <- rpart(quality ~ ., data = wine_train)
m.rpart
```

```
## n= 3750
##
## node), split, n, deviance, yval
##       * denotes terminal node
##
##  1) root 3750 3140.06000 5.886933
##    2) alcohol< 10.85 2473 1510.66200 5.609381
##      4) volatile.acidity>=0.2425 1406  740.15080 5.402560
##        8) volatile.acidity>=0.4225 182    92.99451 4.994505 *
##        9) volatile.acidity< 0.4225 1224  612.34560 5.463235 *
##      5) volatile.acidity< 0.2425 1067  631.12090 5.881912 *
##    3) alcohol>=10.85 1277 1069.95800 6.424432
##      6) free.sulfur.dioxide< 11.5 93    99.18280 5.473118 *
##      7) free.sulfur.dioxide>=11.5 1184  879.99920 6.499155
```

```
##         14) alcohol< 11.85 611  447.38130 6.296236 *
##         15) alcohol>=11.85 573  380.63180 6.715532 *
```

```
#Plotting the classification tree using the rplot function
rpart.plot(m.rpart, digits = 3)
```
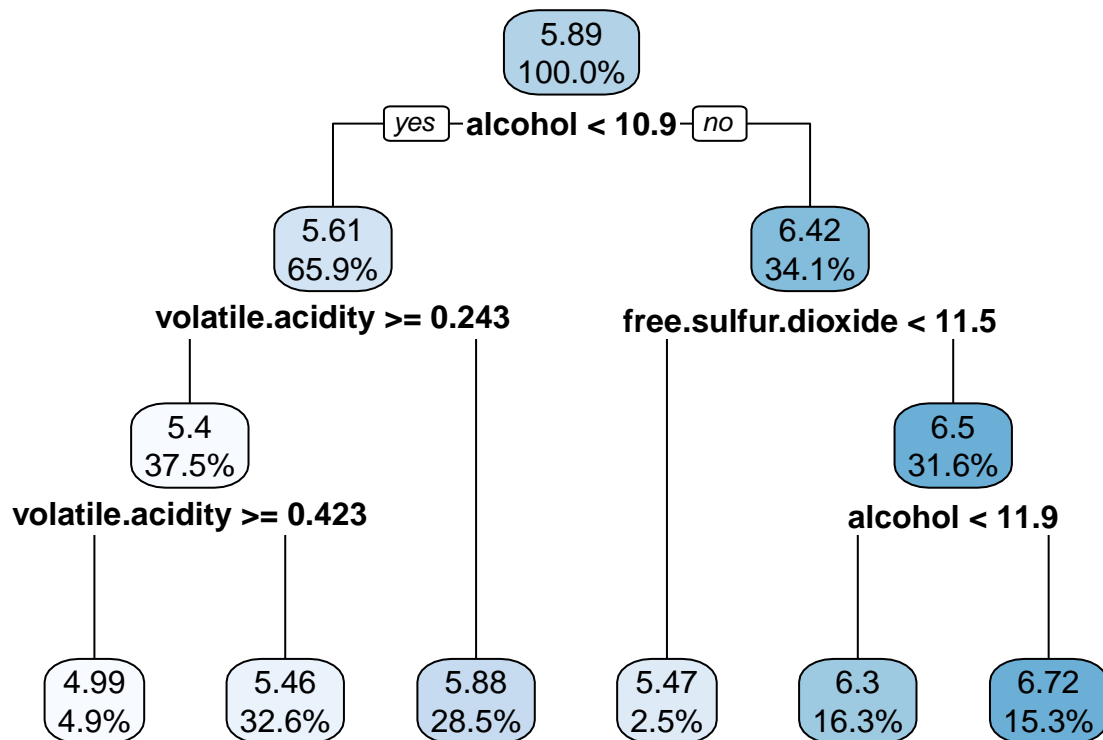


```
rpart.plot(m.rpart, digits = 4, fallen.leaves = TRUE, type = 3, extra = 101)
```
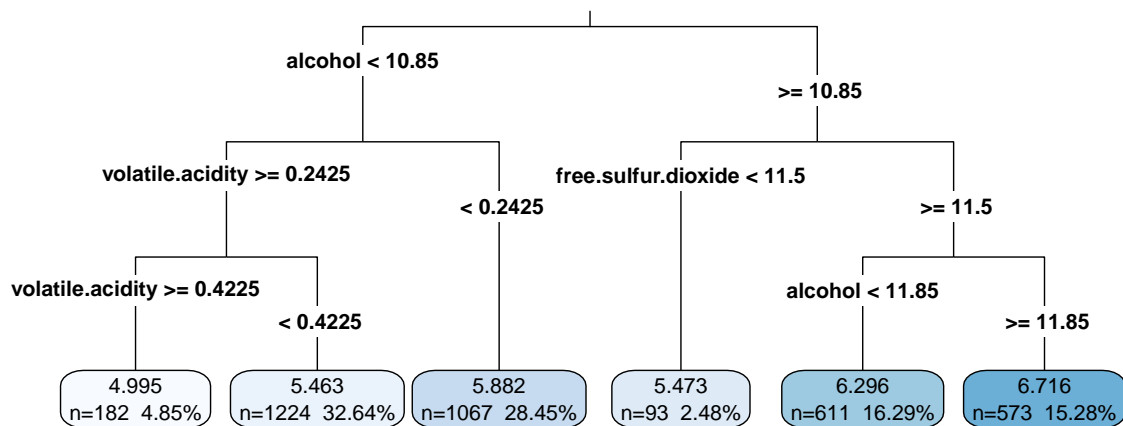
```
#Evaluation of model based on testing data
p.rpart <- predict(m.rpart, wine_test)

#Summarising the predicted values from the model
summary(p.rpart)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   4.995   5.463   5.882   5.999   6.296   6.716
```

```
#SUmmarising the test data nd quality column
summary(wine_test$quality)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
##   3.000   5.000   6.000   5.848   6.000   8.000
```

```
#Comparing the actual and predicted values
cor(p.rpart, wine_test$quality)
```

```
## [1] 0.4931608
```

```
#Creatin a function to calculate Mean Absolute Error(MAE)
MAE <- function(actual, predicted)
  {
```

```
    mean(abs(actual - predicted))
  }

#Claculating the MAE of the model
MAE(p.rpart, wine_test$quality)
```

```
## [1] 0.5732104
```

```
#Calculating the mean of quality ratings
mean(wine_train$quality)
```

```
## [1] 5.886933
```

```
#Calculating the MAE for the mean value
MAE(5.87, wine_test$quality)
```

```
## [1] 0.5815679
```

```
#Using the M5P to improve the model performance
m.m5p <- M5P(quality ~ ., data = wine_train)
m.m5p
```

```
## M5 pruned model tree:
## (using smoothed linear models)
##
## alcohol <= 10.85 :
## |   volatile.acidity <= 0.282 :
## |   |   volatile.acidity <= 0.207 :
## |   |   |   residual.sugar <= 10.1 :
## |   |   |   |   alcohol <= 10.15 :
## |   |   |   |   |   citric.acid <= 0.275 : LM1 (66/46.178%)
## |   |   |   |   |   citric.acid >  0.275 :
## |   |   |   |   |   |   fixed.acidity <= 7.45 :
## |   |   |   |   |   |   |   alcohol <= 9.85 : LM2 (89/64.134%)
## |   |   |   |   |   |   |   alcohol >  9.85 :
## |   |   |   |   |   |   |   |   density <= 0.993 :
## |   |   |   |   |   |   |   |   |   fixed.acidity <= 6.6 : LM3 (7/0%)
## |   |   |   |   |   |   |   |   |   fixed.acidity >  6.6 : LM4 (13/49.88%)
## |   |   |   |   |   |   |   |   density >  0.993 :
## |   |   |   |   |   |   |   |   |   residual.sugar <= 1.85 : LM5 (5/0%)
## |   |   |   |   |   |   |   |   |   residual.sugar >  1.85 : LM6 (7/15.602%)
## |   |   |   |   |   |   fixed.acidity >  7.45 : LM7 (59/74.093%)
## |   |   |   |   alcohol >  10.15 : LM8 (214/81.981%)
## |   |   |   residual.sugar >  10.1 :
## |   |   |   |   citric.acid <= 0.305 :
## |   |   |   |   |   citric.acid <= 0.275 : LM9 (15/50.102%)
## |   |   |   |   |   citric.acid >  0.275 :
## |   |   |   |   |   |   free.sulfur.dioxide <= 30.5 : LM10 (14/0%)
## |   |   |   |   |   |   free.sulfur.dioxide >  30.5 :
## |   |   |   |   |   |   |   chlorides <= 0.055 :
## |   |   |   |   |   |   |   |   free.sulfur.dioxide <= 51.25 :
```

```
## |   |   |   |   |   |   |   |   |   density <= 0.997 :
## |   |   |   |   |   |   |   |   |   |   residual.sugar <= 10.35 : LM11 (3/0%)
## |   |   |   |   |   |   |   |   |   |   residual.sugar >  10.35 : LM12 (3/0%)
## |   |   |   |   |   |   |   |   |   density >  0.997 : LM13 (8/0%)
## |   |   |   |   |   |   |   |   free.sulfur.dioxide >  51.25 : LM14 (6/0%)
## |   |   |   |   |   |   |   chlorides >  0.055 : LM15 (6/0%)
## |   |   |   |   citric.acid >  0.305 :
## |   |   |   |   |   citric.acid <= 0.435 :
## |   |   |   |   |   |   chlorides <= 0.052 :
## |   |   |   |   |   |   |   density <= 0.997 :
## |   |   |   |   |   |   |   |   sulphates <= 0.57 : LM16 (11/18.751%)
## |   |   |   |   |   |   |   |   sulphates >  0.57 : LM17 (6/0%)
## |   |   |   |   |   |   |   density >  0.997 :
## |   |   |   |   |   |   |   |   density <= 0.999 : LM18 (22/0%)
## |   |   |   |   |   |   |   |   density >  0.999 : LM19 (6/28.153%)
## |   |   |   |   |   |   chlorides >  0.052 : LM20 (13/0%)
## |   |   |   |   |   citric.acid >  0.435 :
## |   |   |   |   |   |   citric.acid <= 0.495 :
## |   |   |   |   |   |   |   pH <= 3.205 : LM21 (10/38.853%)
## |   |   |   |   |   |   |   pH >  3.205 :
## |   |   |   |   |   |   |   |   fixed.acidity <= 7.55 : LM22 (3/0%)
## |   |   |   |   |   |   |   |   fixed.acidity >  7.55 : LM23 (3/0%)
## |   |   |   |   |   |   citric.acid >  0.495 :
## |   |   |   |   |   |   |   free.sulfur.dioxide <= 51.5 : LM24 (12/0%)
## |   |   |   |   |   |   |   free.sulfur.dioxide >  51.5 :
## |   |   |   |   |   |   |   |   citric.acid <= 0.67 : LM25 (2/0%)
## |   |   |   |   |   |   |   |   citric.acid >  0.67 : LM26 (5/0%)
## |   |   volatile.acidity >  0.207 :
## |   |   |   alcohol <= 9.95 :
## |   |   |   |   citric.acid <= 0.265 :
## |   |   |   |   |   chlorides <= 0.046 :
## |   |   |   |   |   |   residual.sugar <= 6.25 :
## |   |   |   |   |   |   |   chlorides <= 0.038 : LM27 (5/0%)
## |   |   |   |   |   |   |   chlorides >  0.038 :
## |   |   |   |   |   |   |   |   density <= 0.994 : LM28 (5/0%)
## |   |   |   |   |   |   |   |   density >  0.994 :
## |   |   |   |   |   |   |   |   |   volatile.acidity <= 0.253 : LM29 (2/0%)
## |   |   |   |   |   |   |   |   |   volatile.acidity >  0.253 : LM30 (2/0%)
## |   |   |   |   |   |   residual.sugar >  6.25 : LM31 (51/40.682%)
## |   |   |   |   |   chlorides >  0.046 :
## |   |   |   |   |   |   chlorides <= 0.057 :
## |   |   |   |   |   |   |   pH <= 3.18 : LM32 (24/0%)
## |   |   |   |   |   |   |   pH >  3.18 : LM33 (24/48.999%)
## |   |   |   |   |   |   chlorides >  0.057 : LM34 (27/78.724%)
## |   |   |   |   citric.acid >  0.265 :
## |   |   |   |   |   citric.acid <= 0.425 :
## |   |   |   |   |   |   total.sulfur.dioxide <= 146.5 :
## |   |   |   |   |   |   |   density <= 1 :
## |   |   |   |   |   |   |   |   total.sulfur.dioxide <= 115.5 :
## |   |   |   |   |   |   |   |   |   pH <= 3.175 :
## |   |   |   |   |   |   |   |   |   |   density <= 0.996 : LM35 (14/0%)
## |   |   |   |   |   |   |   |   |   |   density >  0.996 :
## |   |   |   |   |   |   |   |   |   |   |   citric.acid <= 0.305 : LM36 (2/0%)
## |   |   |   |   |   |   |   |   |   |   |   citric.acid >  0.305 : LM37 (3/0%)
```

```
## |   |   |   |   |   |   |   |   |    pH >  3.175 :
## |   |   |   |   |   |   |   |   |   |    residual.sugar <= 1.1 : LM38 (2/0%)
## |   |   |   |   |   |   |   |   |   |    residual.sugar >  1.1 : LM39 (6/0%)
## |   |   |   |   |   |   |   |   total.sulfur.dioxide >  115.5 :
## |   |   |   |   |   |   |   |   |    free.sulfur.dioxide <= 24.5 : LM40 (12/30.204%)
## |   |   |   |   |   |   |   |   |    free.sulfur.dioxide >  24.5 :
## |   |   |   |   |   |   |   |   |   |    volatile.acidity <= 0.235 :
## |   |   |   |   |   |   |   |   |   |   |    pH <= 3.085 : LM41 (9/0%)
## |   |   |   |   |   |   |   |   |   |   |    pH >  3.085 :
## |   |   |   |   |   |   |   |   |   |   |   |    residual.sugar <= 16.75 :
## |   |   |   |   |   |   |   |   |   |   |   |   |    residual.sugar <= 9.65 : LM42 (4/0%)
## |   |   |   |   |   |   |   |   |   |   |   |   |    residual.sugar >  9.65 : LM43 (7/0%)
## |   |   |   |   |   |   |   |   |   |   |   |    residual.sugar >  16.75 : LM44 (5/0%)
## |   |   |   |   |   |   |   |   |   |    volatile.acidity >  0.235 :
## |   |   |   |   |   |   |   |   |   |   |    citric.acid <= 0.35 : LM45 (9/0%)
## |   |   |   |   |   |   |   |   |   |   |    citric.acid >  0.35 : LM46 (5/43.713%)
## |   |   |   |   |   |   |   density >  1 :
## |   |   |   |   |   |   |   |    residual.sugar <= 15.05 : LM47 (5/58.835%)
## |   |   |   |   |   |   |   |    residual.sugar >  15.05 : LM48 (16/0%)
## |   |   |   |   |   |   total.sulfur.dioxide >  146.5 :
## |   |   |   |   |   |   |    fixed.acidity <= 6.65 : LM49 (74/60.126%)
## |   |   |   |   |   |   |    fixed.acidity >  6.65 :
## |   |   |   |   |   |   |   |    pH <= 3.145 : LM50 (102/68.399%)
## |   |   |   |   |   |   |   |    pH >  3.145 : LM51 (77/61.812%)
## |   |   |   |   |   citric.acid >  0.425 : LM52 (135/57.831%)
## |   |   |   alcohol >  9.95 :
## |   |   |   |    free.sulfur.dioxide <= 27.5 :
## |   |   |   |   |    free.sulfur.dioxide <= 13.5 : LM53 (33/98.682%)
## |   |   |   |   |    free.sulfur.dioxide >  13.5 : LM54 (86/62.63%)
## |   |   |   |    free.sulfur.dioxide >  27.5 :
## |   |   |   |   |    pH <= 3.325 :
## |   |   |   |   |   |    volatile.acidity <= 0.263 :
## |   |   |   |   |   |   |    free.sulfur.dioxide <= 55.5 : LM55 (103/57.077%)
## |   |   |   |   |   |   |    free.sulfur.dioxide >  55.5 :
## |   |   |   |   |   |   |   |    residual.sugar <= 8 : LM56 (15/40.324%)
## |   |   |   |   |   |   |   |    residual.sugar >  8 :
## |   |   |   |   |   |   |   |   |    total.sulfur.dioxide <= 155 :
## |   |   |   |   |   |   |   |   |   |    chlorides <= 0.039 : LM57 (2/0%)
## |   |   |   |   |   |   |   |   |   |    chlorides >  0.039 : LM58 (4/0%)
## |   |   |   |   |   |   |   |   |    total.sulfur.dioxide >  155 : LM59 (8/0%)
## |   |   |   |   |   |    volatile.acidity >  0.263 :
## |   |   |   |   |   |   |    chlorides <= 0.044 :
## |   |   |   |   |   |   |   |    total.sulfur.dioxide <= 130.5 : LM60 (5/30.588%)
## |   |   |   |   |   |   |   |    total.sulfur.dioxide >  130.5 :
## |   |   |   |   |   |   |   |   |    density <= 0.992 : LM61 (3/0%)
## |   |   |   |   |   |   |   |   |    density >  0.992 :
## |   |   |   |   |   |   |   |   |   |    fixed.acidity <= 6.85 : LM62 (4/0%)
## |   |   |   |   |   |   |   |   |   |    fixed.acidity >  6.85 :
## |   |   |   |   |   |   |   |   |   |   |    free.sulfur.dioxide <= 30.5 : LM63 (2/0%)
## |   |   |   |   |   |   |   |   |   |   |    free.sulfur.dioxide >  30.5 : LM64 (4/22.369%)
## |   |   |   |   |   |   |    chlorides >  0.044 :
## |   |   |   |   |   |   |   |    density <= 0.995 : LM65 (9/57.073%)
## |   |   |   |   |   |   |   |    density >  0.995 : LM66 (7/0%)
## |   |   |   |   |    pH >  3.325 : LM67 (72/73.853%)
```

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```
## |   volatile.acidity >  0.282 :
## |   |   volatile.acidity <= 0.422 :
## |   |   |   free.sulfur.dioxide <= 21.5 : LM68 (143/70.071%)
## |   |   |   free.sulfur.dioxide >  21.5 :
## |   |   |   |   alcohol <= 9.25 : LM69 (188/55.598%)
## |   |   |   |   alcohol >  9.25 :
## |   |   |   |   |   chlorides <= 0.04 : LM70 (94/71.599%)
## |   |   |   |   |   chlorides >  0.04 :
## |   |   |   |   |   |   volatile.acidity <= 0.305 : LM71 (70/66.297%)
## |   |   |   |   |   |   volatile.acidity >  0.305 :
## |   |   |   |   |   |   |   citric.acid <= 0.345 : LM72 (132/54.604%)
## |   |   |   |   |   |   |   citric.acid >  0.345 :
## |   |   |   |   |   |   |   |   volatile.acidity <= 0.335 :
## |   |   |   |   |   |   |   |   |   chlorides <= 0.044 : LM73 (7/37.561%)
## |   |   |   |   |   |   |   |   |   chlorides >  0.044 : LM74 (20/0%)
## |   |   |   |   |   |   |   |   volatile.acidity >  0.335 :
## |   |   |   |   |   |   |   |   |   pH <= 3.15 :
## |   |   |   |   |   |   |   |   |   |   volatile.acidity <= 0.375 :
## |   |   |   |   |   |   |   |   |   |   |   pH <= 3.055 : LM75 (6/0%)
## |   |   |   |   |   |   |   |   |   |   |   pH >  3.055 :
## |   |   |   |   |   |   |   |   |   |   |   |   sulphates <= 0.42 : LM76 (5/0%)
## |   |   |   |   |   |   |   |   |   |   |   |   sulphates >  0.42 :
## |   |   |   |   |   |   |   |   |   |   |   |   |   pH <= 3.105 : LM77 (5/0%)
## |   |   |   |   |   |   |   |   |   |   |   |   |   pH >  3.105 :
## |   |   |   |   |   |   |   |   |   |   |   |   |   |   volatile.acidity <= 0.355 : LM78 (2/0%)
## |   |   |   |   |   |   |   |   |   |   |   |   |   |   volatile.acidity >  0.355 : LM79 (2/0%)
## |   |   |   |   |   |   |   |   |   |   volatile.acidity >  0.375 : LM80 (10/0%)
## |   |   |   |   |   |   |   |   |   pH >  3.15 :
## |   |   |   |   |   |   |   |   |   |   residual.sugar <= 9.45 :
## |   |   |   |   |   |   |   |   |   |   |   density <= 0.996 : LM81 (4/0%)
## |   |   |   |   |   |   |   |   |   |   |   density >  0.996 : LM82 (4/0%)
## |   |   |   |   |   |   |   |   |   |   residual.sugar >  9.45 : LM83 (7/0%)
## |   |   volatile.acidity >  0.422 :
## |   |   |   volatile.acidity <= 0.587 :
## |   |   |   |   chlorides <= 0.049 :
## |   |   |   |   |   residual.sugar <= 10.65 : LM84 (49/74.502%)
## |   |   |   |   |   residual.sugar >  10.65 : LM85 (17/56.041%)
## |   |   |   |   chlorides >  0.049 : LM86 (71/54.436%)
## |   |   |   volatile.acidity >  0.587 : LM87 (45/63.658%)
## alcohol >  10.85 :
## |   free.sulfur.dioxide <= 20.5 :
## |   |   free.sulfur.dioxide <= 10.5 : LM88 (81/104.574%)
## |   |   free.sulfur.dioxide >  10.5 : LM89 (224/87.002%)
## |   free.sulfur.dioxide >  20.5 :
## |   |   alcohol <= 12.05 :
## |   |   |   fixed.acidity <= 7.35 :
## |   |   |   |   sulphates <= 0.565 :
## |   |   |   |   |   residual.sugar <= 2.05 :
## |   |   |   |   |   |   density <= 0.991 : LM90 (76/70.139%)
## |   |   |   |   |   |   density >  0.991 : LM91 (53/88.647%)
## |   |   |   |   |   residual.sugar >  2.05 :
## |   |   |   |   |   |   free.sulfur.dioxide <= 38.5 :
## |   |   |   |   |   |   |   total.sulfur.dioxide <= 125 : LM92 (66/68.756%)
## |   |   |   |   |   |   |   total.sulfur.dioxide >  125 : LM93 (39/85.617%)
```

```
## |   |   |   |   |   |          free.sulfur.dioxide >  38.5 : LM94 (77/74.028%)
## |   |   |   |     sulphates >  0.565 : LM95 (99/67.429%)
## |   |   |   fixed.acidity >  7.35 :
## |   |   |   |   density <= 0.994 : LM96 (123/81.196%)
## |   |   |   |   density >  0.994 : LM97 (53/63.304%)
## |   |   alcohol >  12.05 :
## |   |   |   sulphates <= 0.475 :
## |   |   |   |   total.sulfur.dioxide <= 112.5 :
## |   |   |   |   |   alcohol <= 12.55 : LM98 (56/55.393%)
## |   |   |   |   |   alcohol >  12.55 :
## |   |   |   |   |   |   citric.acid <= 0.285 :
## |   |   |   |   |   |   |   citric.acid <= 0.245 : LM99 (5/36.972%)
## |   |   |   |   |   |   |   citric.acid >  0.245 : LM100 (5/0%)
## |   |   |   |   |   |   citric.acid >  0.285 :
## |   |   |   |   |   |   |   sulphates <= 0.415 :
## |   |   |   |   |   |   |   |   free.sulfur.dioxide <= 34.5 :
## |   |   |   |   |   |   |   |   |   alcohol <= 13.3 :
## |   |   |   |   |   |   |   |   |   |   total.sulfur.dioxide <= 77.5 : LM101 (5/0%)
## |   |   |   |   |   |   |   |   |   |   total.sulfur.dioxide >  77.5 : LM102 (9/27.113%)
## |   |   |   |   |   |   |   |   |   alcohol >  13.3 : LM103 (4/47.32%)
## |   |   |   |   |   |   |   |   free.sulfur.dioxide >  34.5 : LM104 (5/0%)
## |   |   |   |   |   |   |   sulphates >  0.415 :
## |   |   |   |   |   |   |   |   pH <= 3.225 : LM105 (4/9.044%)
## |   |   |   |   |   |   |   |   pH >  3.225 : LM106 (4/0%)
## |   |   |   |   total.sulfur.dioxide >  112.5 :
## |   |   |   |   |   free.sulfur.dioxide <= 35.5 : LM107 (56/78.811%)
## |   |   |   |   |   free.sulfur.dioxide >  35.5 : LM108 (79/66.147%)
## |   |   |   sulphates >  0.475 :
## |   |   |   |   citric.acid <= 0.345 :
## |   |   |   |   |   pH <= 3.155 : LM109 (22/28.736%)
## |   |   |   |   |   pH >  3.155 :
## |   |   |   |   |   |   residual.sugar <= 1.85 : LM110 (15/69.709%)
## |   |   |   |   |   |   residual.sugar >  1.85 : LM111 (59/58.202%)
## |   |   |   |   citric.acid >  0.345 : LM112 (58/78.288%)
##
## LM num: 1
## quality =
##  0.0496 * volatile.acidity
##  - 0.1195 * citric.acid
##  + 0.0803 * residual.sugar
##  + 0.0388 * chlorides
##  + 1.0289 * free.sulfur.dioxide
##  + 0.0017 * total.sulfur.dioxide
##  - 117.4688 * density
##  - 87.6934 * pH
##  + 1.2306 * sulphates
##  + 0.4379 * alcohol
##  + 207.4502
##
## LM num: 2
## quality =
##  0.0649 * volatile.acidity
##  - 0.1195 * citric.acid
##  - 0.0156 * residual.sugar
```

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```
##   + 0.0337 * chlorides
##   + 0.6633 * free.sulfur.dioxide
##   + 0.0038 * total.sulfur.dioxide
##   - 0.0009 * density
##   - 82.3489 * pH
##   + 1.3566 * sulphates
##   + 0.5559 * alcohol
##   + 84.3863
##
## LM num: 3
## quality =
##   0.152 * fixed.acidity
##   + 0.1047 * volatile.acidity
##   - 0.1195 * citric.acid
##   - 0.0156 * residual.sugar
##   + 0.0391 * chlorides
##   + 0.6633 * free.sulfur.dioxide
##   + 0.0054 * total.sulfur.dioxide
##   - 85.756 * density
##   - 103.5429 * pH
##   + 0.5226 * sulphates
##   + 0.757 * alcohol
##   + 191.2577
##
## LM num: 4
## quality =
##   0.1397 * fixed.acidity
##   + 0.1047 * volatile.acidity
##   - 0.1195 * citric.acid
##   - 0.0156 * residual.sugar
##   + 5.2812 * chlorides
##   + 0.6633 * free.sulfur.dioxide
##   + 0.0054 * total.sulfur.dioxide
##   - 85.756 * density
##   - 103.5429 * pH
##   + 0.5226 * sulphates
##   + 0.757 * alcohol
##   + 191.1871
##
## LM num: 5
## quality =
##   0.1227 * fixed.acidity
##   + 0.1047 * volatile.acidity
##   - 0.1195 * citric.acid
##   - 0.0156 * residual.sugar
##   + 0.0391 * chlorides
##   + 0.6633 * free.sulfur.dioxide
##   + 0.0054 * total.sulfur.dioxide
##   - 111.1648 * density
##   - 103.5429 * pH
##   + 0.5226 * sulphates
##   + 0.757 * alcohol
##   + 216.4052
##
```

```
## LM num: 6
## quality =
##  0.1227 * fixed.acidity
##  + 0.1047 * volatile.acidity
##  - 4.9064 * citric.acid
##  - 0.0156 * residual.sugar
##  + 0.0391 * chlorides
##  + 0.6633 * free.sulfur.dioxide
##  + 0.0043 * total.sulfur.dioxide
##  - 111.1648 * density
##  - 103.5429 * pH
##  + 0.5226 * sulphates
##  + 0.757 * alcohol
##  + 218.1117
##
## LM num: 7
## quality =
##  -0.2034 * fixed.acidity
##  + 0.032 * volatile.acidity
##  - 0.1195 * citric.acid
##  - 0.0156 * residual.sugar
##  + 0.0335 * chlorides
##  + 0.6727 * free.sulfur.dioxide
##  + 0.0039 * total.sulfur.dioxide
##  - 0.0008 * density
##  - 77.0631 * pH
##  + 0.4009 * sulphates
##  + 0.4942 * alcohol
##  + 81.8479
##
## LM num: 8
## quality =
##  0.0209 * volatile.acidity
##  - 0.1195 * citric.acid
##  - 0.0156 * residual.sugar
##  + 0.0146 * chlorides
##  + 0.4346 * free.sulfur.dioxide
##  + 0.0006 * total.sulfur.dioxide
##  - 0.0001 * density
##  - 29.7968 * pH
##  + 0.1267 * sulphates
##  + 0.1532 * alcohol
##  + 34.9695
##
## LM num: 9
## quality =
##  0.5123 * fixed.acidity
##  + 6.1308 * volatile.acidity
##  + 2.6439 * citric.acid
##  - 0.0455 * residual.sugar
##  + 0.0145 * chlorides
##  + 0.4099 * free.sulfur.dioxide
##  + 0 * total.sulfur.dioxide
##  + 0 * density
```

```
##  - 27.6843 * pH
##  + 0.1008 * sulphates
##  + 0.1372 * alcohol
##  + 28.2284
##
## LM num: 10
## quality =
##  0.2052 * fixed.acidity
##  + 0.0196 * volatile.acidity
##  + 1.2384 * citric.acid
##  - 0.1119 * residual.sugar
##  - 8.7167 * chlorides
##  + 0.4088 * free.sulfur.dioxide
##  + 0 * total.sulfur.dioxide
##  + 127.8654 * density
##  - 27.6843 * pH
##  + 0.1008 * sulphates
##  + 0.1372 * alcohol
##  - 93.9949
##
## LM num: 11
## quality =
##  0.2052 * fixed.acidity
##  + 0.0196 * volatile.acidity
##  + 1.2384 * citric.acid
##  - 0.1617 * residual.sugar
##  - 6.1612 * chlorides
##  + 0.4026 * free.sulfur.dioxide
##  + 0 * total.sulfur.dioxide
##  + 164.9383 * density
##  - 27.6843 * pH
##  + 0.1008 * sulphates
##  + 0.1372 * alcohol
##  - 130.1995
##
## LM num: 12
## quality =
##  0.2052 * fixed.acidity
##  + 0.0196 * volatile.acidity
##  + 1.2384 * citric.acid
##  - 0.1617 * residual.sugar
##  - 6.1612 * chlorides
##  + 0.4026 * free.sulfur.dioxide
##  + 0 * total.sulfur.dioxide
##  + 164.9383 * density
##  - 27.6843 * pH
##  + 0.1008 * sulphates
##  + 0.1372 * alcohol
##  - 130.2078
##
## LM num: 13
## quality =
##  0.2052 * fixed.acidity
##  + 0.0196 * volatile.acidity
```

```
##   + 1.2384 * citric.acid
##   - 0.1487 * residual.sugar
##   - 6.1612 * chlorides
##   + 0.4026 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 164.9383 * density
##   - 27.6843 * pH
##   + 0.1008 * sulphates
##   + 0.1372 * alcohol
##   - 130.3516
##
## LM num: 14
## quality =
##   0.2052 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   + 1.2384 * citric.acid
##   - 0.1374 * residual.sugar
##   - 6.1612 * chlorides
##   + 0.4015 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 172.5486 * density
##   - 27.6843 * pH
##   + 0.1008 * sulphates
##   + 0.1372 * alcohol
##   - 138.0831
##
## LM num: 15
## quality =
##   0.2052 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   + 1.2384 * citric.acid
##   - 0.135 * residual.sugar
##   - 6.1612 * chlorides
##   + 0.4025 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 181.3076 * density
##   - 27.6843 * pH
##   + 0.1008 * sulphates
##   + 0.1372 * alcohol
##   - 146.7274
##
## LM num: 16
## quality =
##   0.4254 * fixed.acidity
##   + 1.0239 * volatile.acidity
##   - 0.3325 * citric.acid
##   - 0.0308 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 58.9145 * density
##   - 27.6843 * pH
##   + 1.2124 * sulphates
##   + 0.1372 * alcohol
```

```
##   + 88.0625
##
## LM num: 17
## quality =
##   0.3275 * fixed.acidity
##   + 1.0239 * volatile.acidity
##   - 0.3325 * citric.acid
##   - 0.0308 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 58.9145 * density
##   - 27.6843 * pH
##   + 1.3728 * sulphates
##   + 0.1372 * alcohol
##   + 88.7343
##
## LM num: 18
## quality =
##   0.1428 * fixed.acidity
##   + 0.767 * volatile.acidity
##   - 0.3325 * citric.acid
##   - 0.0204 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 66.5438 * density
##   - 27.6843 * pH
##   + 0.456 * sulphates
##   + 0.1372 * alcohol
##   + 97.9113
##
## LM num: 19
## quality =
##   0.1428 * fixed.acidity
##   + 0.767 * volatile.acidity
##   - 0.3325 * citric.acid
##   + 0.0247 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 83.8395 * density
##   - 27.6843 * pH
##   + 0.456 * sulphates
##   + 0.1372 * alcohol
##   + 114.4554
##
## LM num: 20
## quality =
##   0.0305 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 0.3325 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
```

```
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 27.6843 * pH
##   + 0.2148 * sulphates
##   + 0.1372 * alcohol
##   + 32.9088
##
## LM num: 21
## quality =
##   0.0305 * fixed.acidity
##   + 0.8924 * volatile.acidity
##   + 1.8355 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 26.8063 * pH
##   + 0.2673 * sulphates
##   + 0.4283 * alcohol
##   + 26.2329
##
## LM num: 22
## quality =
##   0.0801 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 1.1333 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 26.6391 * pH
##   + 0.2673 * sulphates
##   + 0.1372 * alcohol
##   + 29.8621
##
## LM num: 23
## quality =
##   0.0801 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 1.1333 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 26.6391 * pH
##   + 0.2673 * sulphates
##   + 0.1372 * alcohol
##   + 29.875
##
## LM num: 24
```

```
## quality =
##   0.0305 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 1.601 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 27.6843 * pH
##   + 0.2673 * sulphates
##   + 0.1372 * alcohol
##   + 33.6464
##
## LM num: 25
## quality =
##   0.0305 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 3.3422 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 27.6843 * pH
##   + 0.2673 * sulphates
##   + 0.1372 * alcohol
##   + 34.8327
##
## LM num: 26
## quality =
##   0.0305 * fixed.acidity
##   + 0.0196 * volatile.acidity
##   - 3.0994 * citric.acid
##   - 0.0455 * residual.sugar
##   + 0.0145 * chlorides
##   + 0.416 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0 * density
##   - 27.6843 * pH
##   + 0.2673 * sulphates
##   + 0.1372 * alcohol
##   + 34.6333
##
## LM num: 27
## quality =
##   0.0703 * fixed.acidity
##   + 0.0156 * volatile.acidity
##   - 0.6574 * citric.acid
##   + 0.0243 * residual.sugar
##   - 67.0175 * chlorides
##   + 0.0315 * free.sulfur.dioxide
##   - 0.0012 * total.sulfur.dioxide
##   - 119.9591 * density
```

```
##  - 30.6011 * pH
##  + 0.919 * sulphates
##  + 0.1648 * alcohol
##  + 156.9039
##
## LM num: 28
## quality =
##  0.0703 * fixed.acidity
##  + 0.0156 * volatile.acidity
##  - 0.6574 * citric.acid
##  + 0.0243 * residual.sugar
##  - 58.9969 * chlorides
##  + 0.0315 * free.sulfur.dioxide
##  - 0.0012 * total.sulfur.dioxide
##  - 150.9471 * density
##  - 30.6011 * pH
##  + 0.919 * sulphates
##  + 0.1648 * alcohol
##  + 187.2329
##
## LM num: 29
## quality =
##  0.0703 * fixed.acidity
##  + 0.4472 * volatile.acidity
##  - 0.6574 * citric.acid
##  + 0.0243 * residual.sugar
##  - 58.9969 * chlorides
##  + 0.0315 * free.sulfur.dioxide
##  - 0.0012 * total.sulfur.dioxide
##  - 153.3651 * density
##  - 30.6011 * pH
##  + 0.919 * sulphates
##  + 0.1648 * alcohol
##  + 189.4848
##
## LM num: 30
## quality =
##  0.0703 * fixed.acidity
##  + 0.4472 * volatile.acidity
##  - 0.6574 * citric.acid
##  + 0.0243 * residual.sugar
##  - 58.9969 * chlorides
##  + 0.0315 * free.sulfur.dioxide
##  - 0.0012 * total.sulfur.dioxide
##  - 153.3651 * density
##  - 30.6011 * pH
##  + 0.919 * sulphates
##  + 0.1648 * alcohol
##  + 189.4879
##
## LM num: 31
## quality =
##  -0.1508 * fixed.acidity
##  + 0.0156 * volatile.acidity
```

```
##   - 0.6574 * citric.acid
##   + 0.0243 * residual.sugar
##   - 9.3904 * chlorides
##   + 0.0214 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 46.7687 * density
##   - 31.5322 * pH
##   + 2.6091 * sulphates
##   + 0.1648 * alcohol
##   + 85.973
##
## LM num: 32
## quality =
##   0.0156 * volatile.acidity
##   - 0.6574 * citric.acid
##   + 0.0344 * residual.sugar
##   - 1.7245 * chlorides
##   + 0.0356 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 93.0156 * density
##   - 30.2048 * pH
##   + 0.5967 * sulphates
##   + 0.1648 * alcohol
##   + 126.2803
##
## LM num: 33
## quality =
##   0.0156 * volatile.acidity
##   - 0.6574 * citric.acid
##   + 0.0344 * residual.sugar
##   - 1.7245 * chlorides
##   + 0.0356 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 93.0156 * density
##   - 30.2048 * pH
##   + 1.711 * sulphates
##   + 0.1648 * alcohol
##   + 125.8596
##
## LM num: 34
## quality =
##   -0.2318 * fixed.acidity
##   + 0.0156 * volatile.acidity
##   - 0.6574 * citric.acid
##   + 0.0409 * residual.sugar
##   - 1.7245 * chlorides
##   + 0.0518 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   - 112.9779 * density
##   - 30.3269 * pH
##   + 0.3189 * sulphates
##   + 0.1648 * alcohol
##   + 147.7215
##
```

```
## LM num: 35
## quality =
##  -0.0373 * fixed.acidity
##  + 0.0097 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0206 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1432 * free.sulfur.dioxide
##  + 0.0012 * total.sulfur.dioxide
##  + 5.3167 * density
##  - 20.8994 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 20.4697
##
## LM num: 36
## quality =
##  -0.0373 * fixed.acidity
##  + 0.0097 * volatile.acidity
##  - 0.6856 * citric.acid
##  - 0.0206 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1432 * free.sulfur.dioxide
##  + 0.0012 * total.sulfur.dioxide
##  + 16.0734 * density
##  - 20.8994 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 9.6669
##
## LM num: 37
## quality =
##  -0.0373 * fixed.acidity
##  + 0.0097 * volatile.acidity
##  - 0.7093 * citric.acid
##  - 0.0206 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1432 * free.sulfur.dioxide
##  + 0.0012 * total.sulfur.dioxide
##  + 16.0734 * density
##  - 20.8994 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 9.6825
##
## LM num: 38
## quality =
##  -0.0373 * fixed.acidity
##  + 0.0097 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0206 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1432 * free.sulfur.dioxide
##  + 0.0012 * total.sulfur.dioxide
```

```
##  - 7.6551 * density
##  - 20.8068 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 33.198
##
## LM num: 39
## quality =
##  -0.0373 * fixed.acidity
##  + 0.0097 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0206 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1432 * free.sulfur.dioxide
##  + 0.0012 * total.sulfur.dioxide
##  - 7.6551 * density
##  - 20.8068 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 33.2209
##
## LM num: 40
## quality =
##  -0.0373 * fixed.acidity
##  - 1.338 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0274 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1405 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.3441 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 54.1599
##
## LM num: 41
## quality =
##  -0.0373 * fixed.acidity
##  - 1.4177 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0274 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1419 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.4879 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 54.5573
##
## LM num: 42
## quality =
##  -0.0373 * fixed.acidity
```

```
##  - 1.4177 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0307 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1419 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.4271 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 54.3559
##
## LM num: 43
## quality =
##  -0.0373 * fixed.acidity
##  - 1.4177 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0302 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1419 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.4271 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 54.3387
##
## LM num: 44
## quality =
##  -0.0373 * fixed.acidity
##  - 1.4177 * volatile.acidity
##  - 1.1116 * citric.acid
##  - 0.0274 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1419 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.4271 * pH
##  - 0.0294 * sulphates
##  + 0.2675 * alcohol
##  + 54.3353
##
## LM num: 45
## quality =
##  -0.0373 * fixed.acidity
##  - 1.7035 * volatile.acidity
##  - 0.2688 * citric.acid
##  - 0.0274 * residual.sugar
##  + 0.0089 * chlorides
##  + 0.1419 * free.sulfur.dioxide
##  + 0.0008 * total.sulfur.dioxide
##  - 26.3738 * density
##  - 21.2186 * pH
##  - 0.0294 * sulphates
```

```
##   + 0.2675 * alcohol
##   + 53.3604
##
## LM num: 46
## quality =
##   -0.0373 * fixed.acidity
##   - 1.7035 * volatile.acidity
##   - 0.1002 * citric.acid
##   - 0.0274 * residual.sugar
##   + 0.0089 * chlorides
##   + 0.1419 * free.sulfur.dioxide
##   + 0.0008 * total.sulfur.dioxide
##   - 26.3738 * density
##   - 21.2186 * pH
##   - 0.0294 * sulphates
##   + 0.2675 * alcohol
##   + 53.3441
##
## LM num: 47
## quality =
##   -0.1902 * fixed.acidity
##   + 0.0097 * volatile.acidity
##   - 0.6172 * citric.acid
##   - 0.0453 * residual.sugar
##   + 0.0089 * chlorides
##   + 0.1451 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0.0008 * density
##   - 21.0931 * pH
##   - 0.0294 * sulphates
##   + 0.2675 * alcohol
##   + 27.6418
##
## LM num: 48
## quality =
##   -0.0964 * fixed.acidity
##   + 0.0097 * volatile.acidity
##   - 0.6172 * citric.acid
##   - 0.0453 * residual.sugar
##   + 0.0089 * chlorides
##   + 0.1451 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0.0008 * density
##   - 21.0931 * pH
##   - 0.0294 * sulphates
##   + 0.2675 * alcohol
##   + 26.779
##
## LM num: 49
## quality =
##   -6.8807 * volatile.acidity
##   - 2.2888 * citric.acid
##   + 0.0028 * residual.sugar
##   + 0.0116 * chlorides
```

```
##   + 0.5173 * free.sulfur.dioxide
##   - 0.0007 * total.sulfur.dioxide
##   - 151.6726 * density
##   - 20.0671 * pH
##   - 0.1039 * sulphates
##   + 0.4164 * alcohol
##   + 176.1433
##
## LM num: 50
## quality =
##   -0.1254 * fixed.acidity
##   - 5.7221 * volatile.acidity
##   - 3.728 * citric.acid
##   - 0.0355 * residual.sugar
##   + 0.0049 * chlorides
##   + 0.3076 * free.sulfur.dioxide
##   + 0.0045 * total.sulfur.dioxide
##   + 0.0007 * density
##   - 5.6339 * pH
##   - 0.2195 * sulphates
##   + 0.4467 * alcohol
##   + 14.807
##
## LM num: 51
## quality =
##   -0.2414 * fixed.acidity
##   - 0.0174 * volatile.acidity
##   + 1.47 * citric.acid
##   - 0.0355 * residual.sugar
##   + 0.0034 * chlorides
##   + 0.3142 * free.sulfur.dioxide
##   - 0.0003 * total.sulfur.dioxide
##   + 0.0007 * density
##   - 1.4331 * pH
##   + 1.2034 * sulphates
##   + 0.4884 * alcohol
##   + 7.8975
##
## LM num: 52
## quality =
##   0.0097 * volatile.acidity
##   - 0.8681 * citric.acid
##   - 0.0868 * residual.sugar
##   + 2.4897 * chlorides
##   + 0.2947 * free.sulfur.dioxide
##   + 0 * total.sulfur.dioxide
##   + 0.0004 * density
##   - 25.9035 * pH
##   + 0.0418 * sulphates
##   + 0.5273 * alcohol
##   + 27.7486
##
## LM num: 53
## quality =
```

```
##   0.0378 * volatile.acidity
##   - 0.2385 * citric.acid
##   + 0.3919 * residual.sugar
##   + 0.0374 * chlorides
##   + 0.0364 * free.sulfur.dioxide
##   + 0.0006 * total.sulfur.dioxide
##   + 0.0015 * density
##   - 113.0943 * pH
##   + 0.4485 * sulphates
##   + 0.177 * alcohol
##   + 115.5411
##
## LM num: 54
## quality =
##   0.0378 * volatile.acidity
##   + 0.5557 * citric.acid
##   + 0.1863 * residual.sugar
##   + 0.0277 * chlorides
##   + 0.0177 * free.sulfur.dioxide
##   + 0.0006 * total.sulfur.dioxide
##   + 0.0008 * density
##   - 79.6938 * pH
##   + 0.3522 * sulphates
##   + 0.5283 * alcohol
##   + 77.6072
##
## LM num: 55
## quality =
##   0.0558 * volatile.acidity
##   - 0.5883 * citric.acid
##   - 0.0908 * residual.sugar
##   + 0.0194 * chlorides
##   - 1.141 * free.sulfur.dioxide
##   - 0.0002 * total.sulfur.dioxide
##   - 0.0004 * density
##   - 52.8732 * pH
##   + 1.4656 * sulphates
##   + 0.3038 * alcohol
##   + 56.6676
##
## LM num: 56
## quality =
##   0.0558 * volatile.acidity
##   - 0.5883 * citric.acid
##   - 0.0908 * residual.sugar
##   + 0.0194 * chlorides
##   - 1.1427 * free.sulfur.dioxide
##   - 0.0062 * total.sulfur.dioxide
##   - 0.0004 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.3038 * alcohol
##   + 58.0593
##
```

```
## LM num: 57
## quality =
##  0.0558 * volatile.acidity
##  - 0.5883 * citric.acid
##  - 0.0908 * residual.sugar
##  - 22.5962 * chlorides
##  - 1.1427 * free.sulfur.dioxide
##  + 0.001 * total.sulfur.dioxide
##  - 0.0004 * density
##  - 52.8732 * pH
##  + 0.2938 * sulphates
##  + 0.3038 * alcohol
##  + 57.8996
##
## LM num: 58
## quality =
##  0.0558 * volatile.acidity
##  - 0.5883 * citric.acid
##  - 0.0908 * residual.sugar
##  - 21.7687 * chlorides
##  - 1.1427 * free.sulfur.dioxide
##  + 0.001 * total.sulfur.dioxide
##  - 0.0004 * density
##  - 52.8732 * pH
##  + 0.2938 * sulphates
##  + 0.3038 * alcohol
##  + 57.8455
##
## LM num: 59
## quality =
##  0.0558 * volatile.acidity
##  - 0.5883 * citric.acid
##  - 0.0908 * residual.sugar
##  - 13.4527 * chlorides
##  - 1.1427 * free.sulfur.dioxide
##  + 0.0009 * total.sulfur.dioxide
##  - 0.0004 * density
##  - 52.8732 * pH
##  + 0.2938 * sulphates
##  + 0.3038 * alcohol
##  + 57.549
##
## LM num: 60
## quality =
##  0.1669 * fixed.acidity
##  + 0.0798 * volatile.acidity
##  - 1.2879 * citric.acid
##  - 0.2725 * residual.sugar
##  + 0.0194 * chlorides
##  - 2.2249 * free.sulfur.dioxide
##  - 0.0063 * total.sulfur.dioxide
##  + 44.5851 * density
##  - 52.8732 * pH
##  + 0.2938 * sulphates
```

```
##   + 0.5177 * alcohol
##   + 12.5094
##
## LM num: 61
## quality =
##   0.0295 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
##   + 0.0194 * chlorides
##   - 2.2249 * free.sulfur.dioxide
##   - 0.0054 * total.sulfur.dioxide
##   + 61.713 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   - 3.8043
##
## LM num: 62
## quality =
##   0.0465 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
##   + 0.0194 * chlorides
##   - 2.2231 * free.sulfur.dioxide
##   - 0.0054 * total.sulfur.dioxide
##   + 53.3503 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   + 4.3304
##
## LM num: 63
## quality =
##   0.0465 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
##   + 0.0194 * chlorides
##   - 2.2219 * free.sulfur.dioxide
##   - 0.0054 * total.sulfur.dioxide
##   + 53.3503 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   + 4.2756
##
## LM num: 64
## quality =
##   0.0451 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
```

```
##   + 0.0194 * chlorides
##   - 2.2221 * free.sulfur.dioxide
##   - 0.0054 * total.sulfur.dioxide
##   + 53.3503 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   + 4.2979
##
## LM num: 65
## quality =
##   0.2279 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
##   + 0.0194 * chlorides
##   - 2.2249 * free.sulfur.dioxide
##   - 0.0033 * total.sulfur.dioxide
##   - 23.573 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   + 79.1277
##
## LM num: 66
## quality =
##   0.1818 * fixed.acidity
##   + 0.0798 * volatile.acidity
##   - 1.2879 * citric.acid
##   - 0.2725 * residual.sugar
##   + 0.0194 * chlorides
##   - 2.2249 * free.sulfur.dioxide
##   - 0.0033 * total.sulfur.dioxide
##   - 25.7159 * density
##   - 52.8732 * pH
##   + 0.2938 * sulphates
##   + 0.5177 * alcohol
##   + 81.5402
##
## LM num: 67
## quality =
##   0.2367 * fixed.acidity
##   + 0.0644 * volatile.acidity
##   - 0.2385 * citric.acid
##   + 0.079 * residual.sugar
##   + 0.0261 * chlorides
##   - 1.2827 * free.sulfur.dioxide
##   + 0.0003 * total.sulfur.dioxide
##   - 345.5155 * density
##   - 72.342 * pH
##   + 0.4309 * sulphates
##   + 0.271 * alcohol
##   + 417.898
##
```

```
## LM num: 68
## quality =
##  -0.1693 * fixed.acidity
##  + 0.0005 * volatile.acidity
##  - 0.0778 * citric.acid
##  - 4.7237 * chlorides
##  - 0.0053 * free.sulfur.dioxide
##  + 0.0004 * total.sulfur.dioxide
##  + 0 * density
##  - 13.0236 * pH
##  + 1.1874 * sulphates
##  + 0.0177 * alcohol
##  + 18.283
##
## LM num: 69
## quality =
##  0.1278 * fixed.acidity
##  + 0.0005 * volatile.acidity
##  - 0.0778 * citric.acid
##  + 0.0054 * chlorides
##  - 0.0269 * free.sulfur.dioxide
##  + 0.0002 * total.sulfur.dioxide
##  + 0 * density
##  - 9.7325 * pH
##  - 1.0363 * sulphates
##  + 0.0177 * alcohol
##  + 14.2795
##
## LM num: 70
## quality =
##  0.011 * volatile.acidity
##  - 0.0778 * citric.acid
##  + 0.0605 * residual.sugar
##  + 0.0157 * chlorides
##  - 0.0301 * free.sulfur.dioxide
##  + 0.0002 * total.sulfur.dioxide
##  - 102.0986 * density
##  - 32.8676 * pH
##  + 0.2018 * sulphates
##  + 0.0177 * alcohol
##  + 136.6965
##
## LM num: 71
## quality =
##  0.1926 * fixed.acidity
##  + 0.0238 * volatile.acidity
##  - 0.0778 * citric.acid
##  + 0.0215 * chlorides
##  - 0.0041 * free.sulfur.dioxide
##  - 0.0048 * total.sulfur.dioxide
##  + 0 * density
##  - 48.3519 * pH
##  + 0.2599 * sulphates
##  + 0.0177 * alcohol
```

```
##   + 51.0641
##
## LM num: 72
## quality =
##   0.0209 * volatile.acidity
##   + 1.0973 * citric.acid
##   + 0.0587 * residual.sugar
##   + 0.022 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0002 * total.sulfur.dioxide
##   - 142.8597 * density
##   - 50.4643 * pH
##   + 0.25 * sulphates
##   + 0.0177 * alcohol
##   + 195.9329
##
## LM num: 73
## quality =
##   0.027 * volatile.acidity
##   - 0.8363 * citric.acid
##   - 1.0441 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   + 0.0003 * density
##   - 64.4052 * pH
##   + 0.3045 * sulphates
##   + 0.0177 * alcohol
##   + 67.6152
##
## LM num: 74
## quality =
##   0.027 * volatile.acidity
##   - 0.2941 * citric.acid
##   - 0.646 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   + 0.0003 * density
##   - 64.4052 * pH
##   + 0.3045 * sulphates
##   + 0.0177 * alcohol
##   + 67.294
##
## LM num: 75
## quality =
##   -1.4942 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.1123 * pH
##   + 0.5305 * sulphates
##   + 0.0177 * alcohol
```

```
##   + 79.9383
##
## LM num: 76
## quality =
##   0.1213 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.3098 * pH
##   + 0.8489 * sulphates
##   + 0.0177 * alcohol
##   + 79.8492
##
## LM num: 77
## quality =
##   0.5923 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.627 * pH
##   + 0.7854 * sulphates
##   + 0.0177 * alcohol
##   + 80.7193
##
## LM num: 78
## quality =
##   0.8827 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.6437 * pH
##   + 0.7854 * sulphates
##   + 0.0177 * alcohol
##   + 80.6638
##
## LM num: 79
## quality =
##   0.8827 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.6437 * pH
```

```
##   + 0.7854 * sulphates
##   + 0.0177 * alcohol
##   + 80.6646
##
## LM num: 80
## quality =
##   -1.8044 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0063 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 16.3185 * density
##   - 63.6906 * pH
##   + 0.3045 * sulphates
##   + 0.0177 * alcohol
##   + 81.9045
##
## LM num: 81
## quality =
##   -1.0917 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0094 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 37.3197 * density
##   - 64.0122 * pH
##   + 0.3045 * sulphates
##   + 0.0177 * alcohol
##   + 103.6611
##
## LM num: 82
## quality =
##   -1.0917 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0094 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 37.3197 * density
##   - 64.0122 * pH
##   + 0.3045 * sulphates
##   + 0.0177 * alcohol
##   + 103.6431
##
## LM num: 83
## quality =
##   -1.0917 * volatile.acidity
##   - 0.0778 * citric.acid
##   + 0.0094 * residual.sugar
##   + 0.0278 * chlorides
##   - 0.0224 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
```

```
##  - 24.4779 * density
##  - 64.0122 * pH
##  + 0.3045 * sulphates
##  + 0.0177 * alcohol
##  + 90.9105
##
## LM num: 84
## quality =
##  -0.0442 * fixed.acidity
##  - 0.0021 * volatile.acidity
##  - 0.2639 * citric.acid
##  + 0.0064 * residual.sugar
##  + 0.0127 * chlorides
##  - 0.3027 * free.sulfur.dioxide
##  + 0.004 * total.sulfur.dioxide
##  + 10.4465 * density
##  - 19.2592 * pH
##  + 0.051 * sulphates
##  + 0.0959 * alcohol
##  + 10.4627
##
## LM num: 85
## quality =
##  -0.0697 * fixed.acidity
##  - 0.0021 * volatile.acidity
##  - 0.2639 * citric.acid
##  + 0.0127 * residual.sugar
##  + 0.0127 * chlorides
##  - 0.3027 * free.sulfur.dioxide
##  + 0.002 * total.sulfur.dioxide
##  + 10.4465 * density
##  - 20.2244 * pH
##  + 0.051 * sulphates
##  + 0.1262 * alcohol
##  + 13.934
##
## LM num: 86
## quality =
##  -0.0177 * fixed.acidity
##  - 0.0021 * volatile.acidity
##  - 0.2639 * citric.acid
##  + 0.0127 * chlorides
##  - 0.2991 * free.sulfur.dioxide
##  + 0.0002 * total.sulfur.dioxide
##  + 9.8391 * density
##  - 20.2244 * pH
##  + 0.051 * sulphates
##  + 0.2593 * alcohol
##  + 12.7934
##
## LM num: 87
## quality =
##  1.1384 * volatile.acidity
##  - 0.4332 * citric.acid
```

```
##   + 0.1153 * residual.sugar
##   + 0.0247 * chlorides
##   - 0.6445 * free.sulfur.dioxide
##   + 0.0002 * total.sulfur.dioxide
##   - 218.6066 * density
##   - 37.5179 * pH
##   - 0.896 * sulphates
##   + 0.0177 * alcohol
##   + 258.5079
##
## LM num: 88
## quality =
##   -0.0318 * fixed.acidity
##   - 0.2828 * volatile.acidity
##   + 1.7345 * citric.acid
##   + 0.1261 * residual.sugar
##   + 0.0055 * chlorides
##   - 0.1249 * free.sulfur.dioxide
##   + 0.0005 * total.sulfur.dioxide
##   - 169.7648 * density
##   - 8.8633 * pH
##   + 0.1416 * sulphates
##   + 0.0516 * alcohol
##   + 180.6069
##
## LM num: 89
## quality =
##   -0.2023 * fixed.acidity
##   - 2.3216 * volatile.acidity
##   - 1.1434 * citric.acid
##   + 0.085 * residual.sugar
##   + 0.0055 * chlorides
##   - 0.242 * free.sulfur.dioxide
##   + 0.0005 * total.sulfur.dioxide
##   - 168.2147 * density
##   - 8.8633 * pH
##   + 0.0892 * sulphates
##   + 0.0516 * alcohol
##   + 183.5076
##
## LM num: 90
## quality =
##   -0.9811 * volatile.acidity
##   - 0.4977 * citric.acid
##   + 0.2969 * residual.sugar
##   + 0.1228 * chlorides
##   - 0.4223 * free.sulfur.dioxide
##   - 0.0025 * total.sulfur.dioxide
##   - 91.1749 * pH
##   + 0.2995 * sulphates
##   + 0.1593 * alcohol
##   + 95.8184
##
## LM num: 91
```

```
## quality =
##   0.281 * fixed.acidity
##   + 0.0497 * volatile.acidity
##   - 0.5876 * citric.acid
##   + 0.5856 * residual.sugar
##   + 0.1536 * chlorides
##   - 0.4365 * free.sulfur.dioxide
##   - 0.0031 * total.sulfur.dioxide
##   - 101.1551 * pH
##   + 0.2995 * sulphates
##   + 0.1593 * alcohol
##   + 103.6026
##
## LM num: 92
## quality =
##   0.0481 * fixed.acidity
##   + 0.1018 * volatile.acidity
##   - 3.1227 * citric.acid
##   + 0.019 * residual.sugar
##   + 0.0504 * chlorides
##   - 0.4223 * free.sulfur.dioxide
##   + 0.005 * total.sulfur.dioxide
##   - 134.7439 * density
##   - 113.0235 * pH
##   + 0.5211 * sulphates
##   + 0.1593 * alcohol
##   + 249.4849
##
## LM num: 93
## quality =
##   0.0721 * fixed.acidity
##   + 0.1018 * volatile.acidity
##   + 2.133 * citric.acid
##   + 0.0286 * residual.sugar
##   + 0.0504 * chlorides
##   - 0.4223 * free.sulfur.dioxide
##   - 0.0005 * total.sulfur.dioxide
##   - 75.3967 * density
##   - 112.9138 * pH
##   + 0.5211 * sulphates
##   + 0.1593 * alcohol
##   + 189.1576
##
## LM num: 94
## quality =
##   -1.5419 * volatile.acidity
##   - 0.3565 * citric.acid
##   + 0.0571 * residual.sugar
##   - 14.5588 * chlorides
##   - 0.4223 * free.sulfur.dioxide
##   - 0.0026 * total.sulfur.dioxide
##   - 114.9384 * density
##   - 131.5293 * pH
##   + 1.9599 * sulphates
```

```
##  + 0.1593 * alcohol
##  + 248.6708
##
## LM num: 95
## quality =
##  0.0484 * volatile.acidity
##  - 0.2028 * citric.acid
##  - 10.4768 * chlorides
##  - 0.4105 * free.sulfur.dioxide
##  + 0.0001 * total.sulfur.dioxide
##  + 71.8209 * density
##  - 59.8368 * pH
##  + 0.2884 * sulphates
##  + 0.2842 * alcohol
##  - 6.4802
##
## LM num: 96
## quality =
##  0.0004 * volatile.acidity
##  - 0.1102 * citric.acid
##  + 0.0077 * residual.sugar
##  + 0.0124 * chlorides
##  - 0.6704 * free.sulfur.dioxide
##  - 0.0001 * total.sulfur.dioxide
##  - 15.8573 * density
##  - 20.9433 * pH
##  + 0.1255 * sulphates
##  + 0.6133 * alcohol
##  + 36.4891
##
## LM num: 97
## quality =
##  -0.2327 * fixed.acidity
##  + 0.0004 * volatile.acidity
##  - 0.1102 * citric.acid
##  + 0.0157 * residual.sugar
##  - 10.1688 * chlorides
##  - 0.6639 * free.sulfur.dioxide
##  - 0.0001 * total.sulfur.dioxide
##  - 292.089 * density
##  - 19.6906 * pH
##  + 0.1255 * sulphates
##  + 0.1425 * alcohol
##  + 315.2155
##
## LM num: 98
## quality =
##  0.0051 * volatile.acidity
##  + 0.005 * citric.acid
##  + 0.2304 * residual.sugar
##  + 0.0177 * chlorides
##  - 3.5522 * free.sulfur.dioxide
##  + 0.0066 * total.sulfur.dioxide
##  + 69.2071 * density
```

```
##   - 21.4691 * pH
##   + 3.2589 * sulphates
##   - 0.0759 * alcohol
##   - 44.6207
##
## LM num: 99
## quality =
##   0.0051 * volatile.acidity
##   - 1.0607 * citric.acid
##   + 0.2921 * residual.sugar
##   - 4.5739 * chlorides
##   - 3.9879 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.2175 * sulphates
##   - 0.0759 * alcohol
##   + 26.2419
##
## LM num: 100
## quality =
##   0.0051 * volatile.acidity
##   + 0.3848 * citric.acid
##   + 0.2921 * residual.sugar
##   - 4.5739 * chlorides
##   - 3.9879 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.2175 * sulphates
##   - 0.0759 * alcohol
##   + 25.9185
##
## LM num: 101
## quality =
##   0.0051 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   - 3.8969 * chlorides
##   - 3.9875 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.7496 * sulphates
##   - 0.1438 * alcohol
##   + 27.1715
##
## LM num: 102
## quality =
##   -0.0787 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   - 3.8969 * chlorides
##   - 3.9875 * free.sulfur.dioxide
##   - 0.0011 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.7496 * sulphates
```

```
##   - 0.1438 * alcohol
##   + 27.0506
##
## LM num: 103
## quality =
##   0.0051 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   - 3.8969 * chlorides
##   - 3.9875 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.7496 * sulphates
##   - 0.1438 * alcohol
##   + 27.1387
##
## LM num: 104
## quality =
##   0.0051 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   - 3.8969 * chlorides
##   - 3.9903 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 21.4691 * pH
##   - 1.7496 * sulphates
##   - 0.1879 * alcohol
##   + 27.788
##
## LM num: 105
## quality =
##   0.0051 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   + 13.0163 * chlorides
##   - 3.9832 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 22.2668 * pH
##   - 2.5266 * sulphates
##   - 0.0759 * alcohol
##   + 28.2301
##
## LM num: 106
## quality =
##   0.0051 * volatile.acidity
##   + 1.1585 * citric.acid
##   + 0.2921 * residual.sugar
##   + 4.7171 * chlorides
##   - 3.9832 * free.sulfur.dioxide
##   - 0.0024 * total.sulfur.dioxide
##   - 22.2668 * pH
##   - 2.5266 * sulphates
##   - 0.0759 * alcohol
##   + 28.5047
```

```
##
## LM num: 107
## quality =
##  -0.0215 * volatile.acidity
##  + 0.2131 * citric.acid
##  + 0.0163 * chlorides
##  - 4.8929 * free.sulfur.dioxide
##  + 0.0059 * total.sulfur.dioxide
##  - 0.0009 * density
##  + 3.6137 * pH
##  + 0.2004 * sulphates
##  - 0.3518 * alcohol
##  + 2.2656
##
## LM num: 108
## quality =
##  -0.1376 * fixed.acidity
##  - 0.015 * volatile.acidity
##  - 0.6288 * citric.acid
##  + 0.0472 * residual.sugar
##  - 25.5055 * chlorides
##  - 4.0634 * free.sulfur.dioxide
##  + 0.0049 * total.sulfur.dioxide
##  + 93.5166 * density
##  - 2.5236 * pH
##  + 0.2004 * sulphates
##  - 0.2717 * alcohol
##  - 82.8348
##
## LM num: 109
## quality =
##  0.0073 * volatile.acidity
##  + 0.0223 * citric.acid
##  - 0.0896 * residual.sugar
##  + 0.0491 * chlorides
##  + 2.7673 * free.sulfur.dioxide
##  + 0.0027 * total.sulfur.dioxide
##  - 0.0004 * density
##  - 105.913 * pH
##  - 0.0516 * sulphates
##  + 0.4989 * alcohol
##  + 109.828
##
## LM num: 110
## quality =
##  0.0073 * volatile.acidity
##  + 0.0223 * citric.acid
##  - 0.6267 * residual.sugar
##  + 0.0683 * chlorides
##  + 5.5425 * free.sulfur.dioxide
##  + 0.0027 * total.sulfur.dioxide
##  - 0.0004 * density
##  - 143.589 * pH
##  + 2.2909 * sulphates
```

```
##   + 1.0975 * alcohol
##   + 142.3524
##
## LM num: 111
## quality =
##   -0.0775 * fixed.acidity
##   + 0.0073 * volatile.acidity
##   + 0.0223 * citric.acid
##   - 0.0896 * residual.sugar
##   + 7.5482 * chlorides
##   + 2.6838 * free.sulfur.dioxide
##   + 0.0027 * total.sulfur.dioxide
##   - 0.0004 * density
##   - 101.1158 * pH
##   + 0.523 * sulphates
##   + 0.6223 * alcohol
##   + 104.6966
##
## LM num: 112
## quality =
##   0.0073 * volatile.acidity
##   + 0.0223 * citric.acid
##   - 0.1362 * residual.sugar
##   - 7.0049 * chlorides
##   - 0.7231 * free.sulfur.dioxide
##   - 0.0038 * total.sulfur.dioxide
##   - 0.0006 * density
##   - 56.9685 * pH
##   - 1.0182 * sulphates
##   + 0.1557 * alcohol
##   + 63.228
##
## Number of Rules : 112
```

```r
#SUmmarising the values generated from the M5P
summary(m.m5p)
```

```
##
## === Summary ===
##
## Correlation coefficient                   -0.2414
## Mean absolute error                      102.3629
## Root mean squared error                  129.5719
## Relative absolute error             14704.2234 %
## Root relative squared error         14159.8116 %
## Total Number of Instances               3750
```

```r
#Evaluating the model based on testing data
p.m5p <- predict(m.m5p, wine_test)

#Summarising the predicted values from the model
summary(p.m5p)
```

```
##    Min. 1st Qu.  Median    Mean 3rd Qu.    Max.
```

```
## -539.90 -165.65 -107.07 -112.27  -33.70   32.49
```

```r
#Comparing the actual and predicted values
cor(p.m5p, wine_test$quality)
```

```
## [1] -0.2036594
```

```r
#Claculating the MAE of the model
MAE(wine_test$quality, p.m5p)
```

```
## [1] 118.6835
```

```r
#Creating a function to calculate the Root Mean Squared Error(RMSE)
RMSE <- function(actual, predicted)
  {
    return(sqrt(sum(actual-predicted)^2/length(actual)))
  }

#Calculating the RMSE
RMSE(wine_test$quality, p.m5p)
```

```
## [1] 4002.081
```