D03\_2.R

B0113

2020-01-09

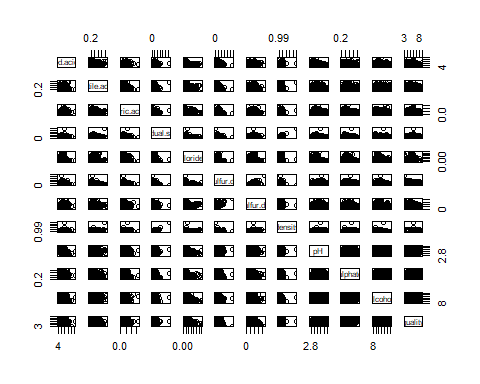
wine <- read.table("winequality-white.csv", sep = ';', header = T)  
str(wine)

## '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 ...

summary(wine)

## fixed.acidity volatile.acidity citric.acid residual.sugar   
## Min. : 3.800 Min. :0.0800 Min. :0.0000 Min. : 0.600   
## 1st Qu.: 6.300 1st Qu.:0.2100 1st Qu.:0.2700 1st Qu.: 1.700   
## Median : 6.800 Median :0.2600 Median :0.3200 Median : 5.200   
## Mean : 6.855 Mean :0.2782 Mean :0.3342 Mean : 6.391   
## 3rd Qu.: 7.300 3rd Qu.:0.3200 3rd Qu.:0.3900 3rd Qu.: 9.900   
## Max. :14.200 Max. :1.1000 Max. :1.6600 Max. :65.800   
## chlorides free.sulfur.dioxide total.sulfur.dioxide density   
## Min. :0.00900 Min. : 2.00 Min. : 9.0 Min. :0.9871   
## 1st Qu.:0.03600 1st Qu.: 23.00 1st Qu.:108.0 1st Qu.:0.9917   
## Median :0.04300 Median : 34.00 Median :134.0 Median :0.9937   
## Mean :0.04577 Mean : 35.31 Mean :138.4 Mean :0.9940   
## 3rd Qu.:0.05000 3rd Qu.: 46.00 3rd Qu.:167.0 3rd Qu.:0.9961   
## Max. :0.34600 Max. :289.00 Max. :440.0 Max. :1.0390   
## pH sulphates alcohol quality   
## Min. :2.720 Min. :0.2200 Min. : 8.00 Min. :3.000   
## 1st Qu.:3.090 1st Qu.:0.4100 1st Qu.: 9.50 1st Qu.:5.000   
## Median :3.180 Median :0.4700 Median :10.40 Median :6.000   
## Mean :3.188 Mean :0.4898 Mean :10.51 Mean :5.878   
## 3rd Qu.:3.280 3rd Qu.:0.5500 3rd Qu.:11.40 3rd Qu.:6.000   
## Max. :3.820 Max. :1.0800 Max. :14.20 Max. :9.000

# Q1. quality와의 상관계수를 구하고,  
# 상관계수 상위 5개의 변수명을 구하십시오.  
pairs(wine)



cor(wine)[12,-12]

## fixed.acidity volatile.acidity citric.acid   
## -0.113662831 -0.194722969 -0.009209091   
## residual.sugar chlorides free.sulfur.dioxide   
## -0.097576829 -0.209934411 0.008158067   
## total.sulfur.dioxide density pH   
## -0.174737218 -0.307123313 0.099427246   
## sulphates alcohol   
## 0.053677877 0.435574715

sort(abs(cor(wine)[12,-12]), decreasing = T)[1:5]

## alcohol density chlorides   
## 0.4355747 0.3071233 0.2099344   
## volatile.acidity total.sulfur.dioxide   
## 0.1947230 0.1747372

cr.top5.names <- names(sort(abs(cor(wine)[12,-12]), decreasing = T)[1:5])  
  
  
# Q2. 종속변수 quality와 1번 문제의 정답인   
# cr.top5.names변수로 구성된  
# 회귀모델의 예측 값을 아래의 데이터를 이용해 구하십시오.  
# 훈련데이터 80%, 검증데이터 20% 사용  
# 랜덤 시드: 123  
  
#"alcohol": 9.2  
#"density": 0.9843  
#"chlorides": 0.067  
#"volatile.acidity": 0.45  
#"total.sulfur.dioxide": 125  
  
set.seed(123)  
idx <- sample(1: nrow(wine), 0.8 \* nrow(wine), replace = F)  
train <- wine[idx,]  
test <- wine[-idx,]  
  
  
model <- lm(quality ~ alcohol + density + chlorides  
 + volatile.acidity + total.sulfur.dioxide,  
 data = train)  
summary(model)

##   
## Call:  
## lm(formula = quality ~ alcohol + density + chlorides + volatile.acidity +   
## total.sulfur.dioxide, data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -3.3925 -0.4919 -0.0365 0.4755 3.0560   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -2.886e+01 6.929e+00 -4.165 3.18e-05 \*\*\*  
## alcohol 3.880e-01 1.659e-02 23.383 < 2e-16 \*\*\*  
## density 3.138e+01 6.862e+00 4.572 4.97e-06 \*\*\*  
## chlorides -1.313e+00 6.058e-01 -2.167 0.0303 \*   
## volatile.acidity -2.076e+00 1.237e-01 -16.792 < 2e-16 \*\*\*  
## total.sulfur.dioxide 7.289e-04 3.433e-04 2.123 0.0338 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.7674 on 3912 degrees of freedom  
## Multiple R-squared: 0.2504, Adjusted R-squared: 0.2495   
## F-statistic: 261.4 on 5 and 3912 DF, p-value: < 2.2e-16

test$pred <- predict(model, newdata = test)  
head(test[12:13])

## quality pred  
## 6 6 5.707876  
## 8 6 5.469174  
## 23 8 5.858240  
## 24 5 4.563986  
## 38 6 5.915574  
## 48 5 5.239242

new\_df <- data.frame("alcohol" = 9.2, "density" = 0.9843,  
 "chlorides" = 0.067,  
 "volatile.acidity"= 0.45,  
 "total.sulfur.dioxide" = 125)  
new\_df

## alcohol density chlorides volatile.acidity total.sulfur.dioxide  
## 1 9.2 0.9843 0.067 0.45 125

pred2 <- predict(model, newdata = new\_df)  
pred2

## 1   
## 4.664928

# cr.top5.names변수 이용하는 방법 : paste() 활용해서  
# fm.top5.names 만들고  
# lm(as.formula(fm.top5.names, data = ...))  
  
  
  
# Q3. model.cr.top5(내가 쓴 변수명은 model)와  
# 모든 변수를 가진 model.full과의  
# RMSE 지표를 비교하십시오.  
model.full <- lm(quality ~ ., data = train)  
summary(model.full)

##   
## Call:  
## lm(formula = quality ~ ., data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -3.6798 -0.4948 -0.0393 0.4639 3.1130   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 1.409e+02 2.058e+01 6.846 8.78e-12 \*\*\*  
## fixed.acidity 6.293e-02 2.349e-02 2.679 0.007419 \*\*   
## volatile.acidity -1.905e+00 1.269e-01 -15.006 < 2e-16 \*\*\*  
## citric.acid -1.046e-03 1.069e-01 -0.010 0.992191   
## residual.sugar 7.731e-02 8.319e-03 9.293 < 2e-16 \*\*\*  
## chlorides -2.131e-01 6.119e-01 -0.348 0.727661   
## free.sulfur.dioxide 3.128e-03 9.318e-04 3.356 0.000798 \*\*\*  
## total.sulfur.dioxide -2.223e-04 4.246e-04 -0.523 0.600663   
## density -1.407e+02 2.089e+01 -6.734 1.89e-11 \*\*\*  
## pH 5.924e-01 1.171e-01 5.059 4.41e-07 \*\*\*  
## sulphates 6.036e-01 1.111e-01 5.434 5.83e-08 \*\*\*  
## alcohol 2.035e-01 2.661e-02 7.648 2.56e-14 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.753 on 3906 degrees of freedom  
## Multiple R-squared: 0.2794, Adjusted R-squared: 0.2773   
## F-statistic: 137.7 on 11 and 3906 DF, p-value: < 2.2e-16

full\_pred <- predict(model.full, newdata = test)  
test$full\_pred <- full\_pred  
head(test[12:14])

## quality pred full\_pred  
## 6 6 5.707876 5.757802  
## 8 6 5.469174 5.563753  
## 23 8 5.858240 5.866480  
## 24 5 4.563986 4.481741  
## 38 6 5.915574 5.851339  
## 48 5 5.239242 5.324599

rmse <- function(yi, yi\_hat) {  
 return(sqrt(mean((yi - yi\_hat)^2)))  
}  
rmse(test$quality, test$pred)

## [1] 0.7706527

rmse(test$quality, test$full\_pred)

## [1] 0.7457548

# full이 더 좋음  
  
  
library(MASS)  
model.AIC <- stepAIC(model.full, scope = list(upper = ~.,  
 lower = ~ 1))

## Start: AIC=-2211.11  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol  
##   
## Df Sum of Sq RSS AIC  
## - citric.acid 1 0.000 2214.7 -2213.1  
## - chlorides 1 0.069 2214.8 -2213.0  
## - total.sulfur.dioxide 1 0.155 2214.8 -2212.8  
## <none> 2214.7 -2211.1  
## - fixed.acidity 1 4.069 2218.8 -2205.9  
## - free.sulfur.dioxide 1 6.387 2221.1 -2201.8  
## - pH 1 14.511 2229.2 -2187.5  
## - sulphates 1 16.745 2231.4 -2183.6  
## - density 1 25.715 2240.4 -2167.9  
## - alcohol 1 33.163 2247.8 -2154.9  
## - residual.sugar 1 48.970 2263.7 -2127.4  
## - volatile.acidity 1 127.678 2342.4 -1993.5  
##   
## Step: AIC=-2213.11  
## quality ~ fixed.acidity + volatile.acidity + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol  
##   
## Df Sum of Sq RSS AIC  
## - chlorides 1 0.070 2214.8 -2215.0  
## - total.sulfur.dioxide 1 0.156 2214.8 -2214.8  
## <none> 2214.7 -2213.1  
## + citric.acid 1 0.000 2214.7 -2211.1  
## - fixed.acidity 1 4.125 2218.8 -2207.8  
## - free.sulfur.dioxide 1 6.393 2221.1 -2203.8  
## - pH 1 14.633 2229.3 -2189.3  
## - sulphates 1 16.766 2231.4 -2185.6  
## - density 1 25.833 2240.5 -2169.7  
## - alcohol 1 33.418 2248.1 -2156.4  
## - residual.sugar 1 49.063 2263.8 -2129.3  
## - volatile.acidity 1 131.511 2346.2 -1989.1  
##   
## Step: AIC=-2214.99  
## quality ~ fixed.acidity + volatile.acidity + residual.sugar +   
## free.sulfur.dioxide + total.sulfur.dioxide + density + pH +   
## sulphates + alcohol  
##   
## Df Sum of Sq RSS AIC  
## - total.sulfur.dioxide 1 0.161 2214.9 -2216.7  
## <none> 2214.8 -2215.0  
## + chlorides 1 0.070 2214.7 -2213.1  
## + citric.acid 1 0.001 2214.8 -2213.0  
## - fixed.acidity 1 4.399 2219.2 -2209.2  
## - free.sulfur.dioxide 1 6.362 2221.1 -2205.8  
## - pH 1 15.458 2230.2 -2189.7  
## - sulphates 1 16.848 2231.6 -2187.3  
## - density 1 27.086 2241.8 -2169.4  
## - alcohol 1 33.446 2248.2 -2158.3  
## - residual.sugar 1 51.963 2266.7 -2126.1  
## - volatile.acidity 1 133.068 2347.8 -1988.4  
##   
## Step: AIC=-2216.7  
## quality ~ fixed.acidity + volatile.acidity + residual.sugar +   
## free.sulfur.dioxide + density + pH + sulphates + alcohol  
##   
## Df Sum of Sq RSS AIC  
## <none> 2214.9 -2216.7  
## + total.sulfur.dioxide 1 0.161 2214.8 -2215.0  
## + chlorides 1 0.075 2214.8 -2214.8  
## + citric.acid 1 0.002 2214.9 -2214.7  
## - fixed.acidity 1 4.452 2219.4 -2210.8  
## - free.sulfur.dioxide 1 8.109 2223.0 -2204.4  
## - pH 1 15.510 2230.4 -2191.4  
## - sulphates 1 16.693 2231.6 -2189.3  
## - density 1 28.966 2243.9 -2167.8  
## - alcohol 1 33.339 2248.2 -2160.2  
## - residual.sugar 1 53.624 2268.5 -2125.0  
## - volatile.acidity 1 139.766 2354.7 -1979.0

summary(model.AIC)

##   
## Call:  
## lm(formula = quality ~ fixed.acidity + volatile.acidity + residual.sugar +   
## free.sulfur.dioxide + density + pH + sulphates + alcohol,   
## data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -3.6691 -0.4965 -0.0400 0.4623 3.1173   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 1.442e+02 1.987e+01 7.257 4.74e-13 \*\*\*  
## fixed.acidity 6.453e-02 2.302e-02 2.803 0.005089 \*\*   
## volatile.acidity -1.921e+00 1.223e-01 -15.706 < 2e-16 \*\*\*  
## residual.sugar 7.847e-02 8.066e-03 9.728 < 2e-16 \*\*\*  
## free.sulfur.dioxide 2.822e-03 7.459e-04 3.783 0.000157 \*\*\*  
## density -1.440e+02 2.015e+01 -7.150 1.03e-12 \*\*\*  
## pH 6.005e-01 1.148e-01 5.232 1.77e-07 \*\*\*  
## sulphates 6.001e-01 1.106e-01 5.428 6.05e-08 \*\*\*  
## alcohol 2.031e-01 2.648e-02 7.671 2.15e-14 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.7527 on 3909 degrees of freedom  
## Multiple R-squared: 0.2793, Adjusted R-squared: 0.2778   
## F-statistic: 189.3 on 8 and 3909 DF, p-value: < 2.2e-16

test$pred\_AIC <- predict(model.AIC, newdata = test)  
rmse(test$quality, test$pred\_AIC)

## [1] 0.7458752

model.AIC2 <- stepAIC(model.full, scope = list(upper = ~.^2,  
 lower = ~ 1))

## Start: AIC=-2211.11  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol  
##   
## Df Sum of Sq RSS AIC  
## + free.sulfur.dioxide:total.sulfur.dioxide 1 66.404 2148.3 -2328.4  
## + volatile.acidity:alcohol 1 26.288 2188.4 -2255.9  
## + free.sulfur.dioxide:density 1 22.542 2192.1 -2249.2  
## + pH:alcohol 1 19.062 2195.6 -2243.0  
## + residual.sugar:free.sulfur.dioxide 1 18.859 2195.8 -2242.6  
## + free.sulfur.dioxide:alcohol 1 17.128 2197.6 -2239.5  
## + total.sulfur.dioxide:pH 1 15.918 2198.8 -2237.4  
## + total.sulfur.dioxide:sulphates 1 13.984 2200.7 -2233.9  
## + fixed.acidity:free.sulfur.dioxide 1 13.049 2201.6 -2232.3  
## + free.sulfur.dioxide:pH 1 12.648 2202.0 -2231.6  
## + fixed.acidity:residual.sugar 1 12.046 2202.6 -2230.5  
## + density:pH 1 12.031 2202.7 -2230.4  
## + residual.sugar:density 1 11.188 2203.5 -2228.9  
## + fixed.acidity:density 1 10.750 2203.9 -2228.2  
## + chlorides:pH 1 10.456 2204.2 -2227.7  
## + residual.sugar:pH 1 9.825 2204.9 -2226.5  
## + chlorides:alcohol 1 9.547 2205.1 -2226.0  
## + fixed.acidity:citric.acid 1 8.507 2206.2 -2224.2  
## + chlorides:sulphates 1 8.272 2206.4 -2223.8  
## + fixed.acidity:total.sulfur.dioxide 1 7.036 2207.7 -2221.6  
## + fixed.acidity:alcohol 1 6.210 2208.5 -2220.1  
## + citric.acid:pH 1 5.648 2209.0 -2219.1  
## + density:alcohol 1 5.231 2209.4 -2218.4  
## + pH:sulphates 1 5.175 2209.5 -2218.3  
## + fixed.acidity:pH 1 4.987 2209.7 -2217.9  
## + volatile.acidity:chlorides 1 4.912 2209.8 -2217.8  
## + volatile.acidity:pH 1 3.569 2211.1 -2215.4  
## + total.sulfur.dioxide:alcohol 1 3.059 2211.6 -2214.5  
## + citric.acid:chlorides 1 2.961 2211.7 -2214.3  
## + citric.acid:sulphates 1 2.913 2211.8 -2214.3  
## + residual.sugar:sulphates 1 2.901 2211.8 -2214.2  
## + chlorides:total.sulfur.dioxide 1 2.662 2212.0 -2213.8  
## - citric.acid 1 0.000 2214.7 -2213.1  
## + sulphates:alcohol 1 2.200 2212.5 -2213.0  
## - chlorides 1 0.069 2214.8 -2213.0  
## - total.sulfur.dioxide 1 0.155 2214.8 -2212.8  
## + density:sulphates 1 1.994 2212.7 -2212.6  
## + volatile.acidity:citric.acid 1 1.845 2212.8 -2212.4  
## + citric.acid:free.sulfur.dioxide 1 1.567 2213.1 -2211.9  
## + volatile.acidity:residual.sugar 1 1.390 2213.3 -2211.6  
## + fixed.acidity:sulphates 1 1.335 2213.3 -2211.5  
## + residual.sugar:chlorides 1 1.281 2213.4 -2211.4  
## + fixed.acidity:chlorides 1 1.250 2213.4 -2211.3  
## + total.sulfur.dioxide:density 1 1.156 2213.5 -2211.2  
## <none> 2214.7 -2211.1  
## + residual.sugar:total.sulfur.dioxide 1 1.086 2213.6 -2211.0  
## + citric.acid:residual.sugar 1 0.939 2213.7 -2210.8  
## + chlorides:density 1 0.926 2213.8 -2210.8  
## + chlorides:free.sulfur.dioxide 1 0.649 2214.0 -2210.3  
## + volatile.acidity:free.sulfur.dioxide 1 0.630 2214.1 -2210.2  
## + fixed.acidity:volatile.acidity 1 0.495 2214.2 -2210.0  
## + free.sulfur.dioxide:sulphates 1 0.414 2214.3 -2209.8  
## + citric.acid:alcohol 1 0.334 2214.3 -2209.7  
## + residual.sugar:alcohol 1 0.292 2214.4 -2209.6  
## + volatile.acidity:total.sulfur.dioxide 1 0.218 2214.5 -2209.5  
## + citric.acid:total.sulfur.dioxide 1 0.202 2214.5 -2209.5  
## + volatile.acidity:density 1 0.177 2214.5 -2209.4  
## + volatile.acidity:sulphates 1 0.097 2214.6 -2209.3  
## + citric.acid:density 1 0.003 2214.7 -2209.1  
## - fixed.acidity 1 4.069 2218.8 -2205.9  
## - free.sulfur.dioxide 1 6.387 2221.1 -2201.8  
## - pH 1 14.511 2229.2 -2187.5  
## - sulphates 1 16.745 2231.4 -2183.6  
## - density 1 25.715 2240.4 -2167.9  
## - alcohol 1 33.163 2247.8 -2154.9  
## - residual.sugar 1 48.970 2263.7 -2127.4  
## - volatile.acidity 1 127.678 2342.4 -1993.5  
##   
## Step: AIC=-2328.38  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide  
##   
## Df Sum of Sq RSS AIC  
## + volatile.acidity:alcohol 1 26.568 2121.7 -2375.1  
## + residual.sugar:free.sulfur.dioxide 1 18.716 2129.6 -2360.7  
## + pH:alcohol 1 18.345 2129.9 -2360.0  
## + fixed.acidity:residual.sugar 1 12.760 2135.5 -2349.7  
## + free.sulfur.dioxide:density 1 12.407 2135.9 -2349.1  
## + density:pH 1 12.342 2135.9 -2349.0  
## + residual.sugar:density 1 11.416 2136.9 -2347.3  
## + residual.sugar:pH 1 10.667 2137.6 -2345.9  
## + fixed.acidity:density 1 10.557 2137.7 -2345.7  
## + chlorides:pH 1 9.414 2138.9 -2343.6  
## + chlorides:alcohol 1 8.827 2139.4 -2342.5  
## + fixed.acidity:citric.acid 1 7.885 2140.4 -2340.8  
## + chlorides:sulphates 1 7.076 2141.2 -2339.3  
## + total.sulfur.dioxide:pH 1 6.735 2141.5 -2338.7  
## + fixed.acidity:free.sulfur.dioxide 1 6.639 2141.6 -2338.5  
## + free.sulfur.dioxide:alcohol 1 6.623 2141.7 -2338.5  
## + fixed.acidity:alcohol 1 6.391 2141.9 -2338.1  
## + pH:sulphates 1 5.371 2142.9 -2336.2  
## + total.sulfur.dioxide:sulphates 1 5.239 2143.0 -2335.9  
## + density:alcohol 1 5.131 2143.2 -2335.8  
## + volatile.acidity:chlorides 1 4.813 2143.5 -2335.2  
## + citric.acid:pH 1 4.708 2143.6 -2335.0  
## + volatile.acidity:pH 1 3.888 2144.4 -2333.5  
## + fixed.acidity:total.sulfur.dioxide 1 3.616 2144.7 -2333.0  
## + fixed.acidity:pH 1 3.161 2145.1 -2332.2  
## + citric.acid:chlorides 1 2.880 2145.4 -2331.6  
## + citric.acid:sulphates 1 2.799 2145.5 -2331.5  
## + residual.sugar:sulphates 1 2.406 2145.9 -2330.8  
## + free.sulfur.dioxide:sulphates 1 2.394 2145.9 -2330.8  
## - citric.acid 1 0.028 2148.3 -2330.3  
## + sulphates:alcohol 1 2.062 2146.2 -2330.1  
## + volatile.acidity:citric.acid 1 1.917 2146.4 -2329.9  
## - chlorides 1 0.366 2148.6 -2329.7  
## + density:sulphates 1 1.615 2146.7 -2329.3  
## + volatile.acidity:residual.sugar 1 1.495 2146.8 -2329.1  
## + fixed.acidity:sulphates 1 1.350 2146.9 -2328.8  
## + chlorides:total.sulfur.dioxide 1 1.213 2147.1 -2328.6  
## <none> 2148.3 -2328.4  
## + residual.sugar:chlorides 1 1.066 2147.2 -2328.3  
## + chlorides:density 1 0.990 2147.3 -2328.2  
## + fixed.acidity:volatile.acidity 1 0.950 2147.3 -2328.1  
## + fixed.acidity:chlorides 1 0.927 2147.3 -2328.1  
## + citric.acid:total.sulfur.dioxide 1 0.739 2147.5 -2327.7  
## + citric.acid:residual.sugar 1 0.678 2147.6 -2327.6  
## + free.sulfur.dioxide:pH 1 0.588 2147.7 -2327.4  
## + residual.sugar:alcohol 1 0.350 2147.9 -2327.0  
## + citric.acid:alcohol 1 0.270 2148.0 -2326.9  
## + volatile.acidity:total.sulfur.dioxide 1 0.266 2148.0 -2326.9  
## + total.sulfur.dioxide:alcohol 1 0.170 2148.1 -2326.7  
## + volatile.acidity:density 1 0.149 2148.1 -2326.7  
## + volatile.acidity:sulphates 1 0.109 2148.2 -2326.6  
## + volatile.acidity:free.sulfur.dioxide 1 0.092 2148.2 -2326.6  
## + residual.sugar:total.sulfur.dioxide 1 0.083 2148.2 -2326.5  
## + total.sulfur.dioxide:density 1 0.073 2148.2 -2326.5  
## + chlorides:free.sulfur.dioxide 1 0.070 2148.2 -2326.5  
## + citric.acid:free.sulfur.dioxide 1 0.010 2148.3 -2326.4  
## + citric.acid:density 1 0.008 2148.3 -2326.4  
## - fixed.acidity 1 4.592 2152.9 -2322.0  
## - pH 1 13.720 2162.0 -2305.4  
## - sulphates 1 16.037 2164.3 -2301.2  
## - density 1 23.743 2172.0 -2287.3  
## - alcohol 1 33.589 2181.9 -2269.6  
## - residual.sugar 1 43.490 2191.8 -2251.9  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 66.404 2214.7 -2211.1  
## - volatile.acidity 1 111.773 2260.1 -2131.7  
##   
## Step: AIC=-2375.14  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol  
##   
## Df Sum of Sq RSS AIC  
## + residual.sugar:free.sulfur.dioxide 1 18.566 2103.1 -2407.6  
## + pH:alcohol 1 15.808 2105.9 -2402.4  
## + free.sulfur.dioxide:density 1 14.515 2107.2 -2400.0  
## + fixed.acidity:residual.sugar 1 11.334 2110.4 -2394.1  
## + density:pH 1 11.181 2110.5 -2393.8  
## + free.sulfur.dioxide:alcohol 1 11.145 2110.6 -2393.8  
## + residual.sugar:density 1 11.082 2110.6 -2393.7  
## + residual.sugar:pH 1 9.436 2112.3 -2390.6  
## + fixed.acidity:citric.acid 1 9.295 2112.4 -2390.3  
## + chlorides:pH 1 9.280 2112.4 -2390.3  
## + volatile.acidity:density 1 9.170 2112.5 -2390.1  
## + fixed.acidity:density 1 8.385 2113.3 -2388.7  
## + chlorides:alcohol 1 8.124 2113.6 -2388.2  
## + total.sulfur.dioxide:pH 1 6.572 2115.1 -2385.3  
## + fixed.acidity:free.sulfur.dioxide 1 5.924 2115.8 -2384.1  
## + volatile.acidity:residual.sugar 1 5.867 2115.8 -2384.0  
## + citric.acid:pH 1 5.271 2116.4 -2382.9  
## + chlorides:sulphates 1 4.975 2116.7 -2382.3  
## + total.sulfur.dioxide:sulphates 1 4.288 2117.4 -2381.1  
## + fixed.acidity:alcohol 1 3.997 2117.7 -2380.5  
## + volatile.acidity:citric.acid 1 3.940 2117.8 -2380.4  
## + pH:sulphates 1 3.623 2118.1 -2379.8  
## + free.sulfur.dioxide:sulphates 1 3.508 2118.2 -2379.6  
## + fixed.acidity:pH 1 3.488 2118.2 -2379.6  
## + volatile.acidity:total.sulfur.dioxide 1 3.179 2118.5 -2379.0  
## + fixed.acidity:total.sulfur.dioxide 1 3.080 2118.6 -2378.8  
## + density:alcohol 1 2.949 2118.8 -2378.6  
## - citric.acid 1 0.004 2121.7 -2377.1  
## + chlorides:density 1 2.100 2119.6 -2377.0  
## - chlorides 1 0.136 2121.8 -2376.9  
## + residual.sugar:sulphates 1 2.020 2119.7 -2376.9  
## + citric.acid:chlorides 1 1.356 2120.3 -2375.6  
## + volatile.acidity:pH 1 1.313 2120.4 -2375.6  
## + fixed.acidity:sulphates 1 1.236 2120.5 -2375.4  
## + density:sulphates 1 1.119 2120.6 -2375.2  
## + fixed.acidity:chlorides 1 1.116 2120.6 -2375.2  
## <none> 2121.7 -2375.1  
## + volatile.acidity:sulphates 1 1.056 2120.7 -2375.1  
## + citric.acid:sulphates 1 0.975 2120.7 -2374.9  
## + citric.acid:total.sulfur.dioxide 1 0.865 2120.8 -2374.7  
## + sulphates:alcohol 1 0.821 2120.9 -2374.7  
## + citric.acid:residual.sugar 1 0.794 2120.9 -2374.6  
## + free.sulfur.dioxide:pH 1 0.595 2121.1 -2374.2  
## + chlorides:total.sulfur.dioxide 1 0.494 2121.2 -2374.1  
## + citric.acid:alcohol 1 0.425 2121.3 -2373.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.388 2121.3 -2373.9  
## + chlorides:free.sulfur.dioxide 1 0.356 2121.3 -2373.8  
## + residual.sugar:alcohol 1 0.318 2121.4 -2373.7  
## + total.sulfur.dioxide:alcohol 1 0.303 2121.4 -2373.7  
## + residual.sugar:chlorides 1 0.239 2121.5 -2373.6  
## + citric.acid:density 1 0.236 2121.5 -2373.6  
## + total.sulfur.dioxide:density 1 0.187 2121.5 -2373.5  
## + volatile.acidity:chlorides 1 0.039 2121.7 -2373.2  
## + fixed.acidity:volatile.acidity 1 0.033 2121.7 -2373.2  
## + citric.acid:free.sulfur.dioxide 1 0.012 2121.7 -2373.2  
## + residual.sugar:total.sulfur.dioxide 1 0.007 2121.7 -2373.2  
## - fixed.acidity 1 5.721 2127.4 -2366.6  
## - pH 1 15.091 2136.8 -2349.4  
## - sulphates 1 16.146 2137.9 -2347.4  
## - volatile.acidity:alcohol 1 26.568 2148.3 -2328.4  
## - density 1 27.044 2148.8 -2327.5  
## - residual.sugar 1 43.903 2165.6 -2296.9  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 66.684 2188.4 -2255.9  
##   
## Step: AIC=-2407.58  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide  
##   
## Df Sum of Sq RSS AIC  
## + pH:alcohol 1 15.561 2087.6 -2434.7  
## + density:pH 1 12.438 2090.7 -2428.8  
## + fixed.acidity:free.sulfur.dioxide 1 11.017 2092.1 -2426.2  
## + fixed.acidity:residual.sugar 1 10.011 2093.1 -2424.3  
## + total.sulfur.dioxide:pH 1 10.000 2093.1 -2424.2  
## + residual.sugar:pH 1 9.449 2093.7 -2423.2  
## + fixed.acidity:citric.acid 1 8.870 2094.3 -2422.1  
## + chlorides:pH 1 8.668 2094.5 -2421.8  
## + density:alcohol 1 7.758 2095.4 -2420.1  
## + fixed.acidity:density 1 7.502 2095.6 -2419.6  
## + chlorides:alcohol 1 7.354 2095.8 -2419.3  
## + residual.sugar:total.sulfur.dioxide 1 6.559 2096.6 -2417.8  
## + residual.sugar:density 1 6.369 2096.8 -2417.5  
## + total.sulfur.dioxide:density 1 6.131 2097.0 -2417.0  
## + citric.acid:pH 1 5.404 2097.7 -2415.7  
## + fixed.acidity:alcohol 1 4.997 2098.2 -2414.9  
## + chlorides:sulphates 1 4.813 2098.3 -2414.6  
## + fixed.acidity:total.sulfur.dioxide 1 4.807 2098.3 -2414.5  
## + total.sulfur.dioxide:sulphates 1 4.586 2098.6 -2414.1  
## + fixed.acidity:pH 1 3.844 2099.3 -2412.7  
## + free.sulfur.dioxide:pH 1 3.531 2099.6 -2412.2  
## + volatile.acidity:density 1 3.060 2100.1 -2411.3  
## + volatile.acidity:citric.acid 1 2.935 2100.2 -2411.1  
## + free.sulfur.dioxide:alcohol 1 2.836 2100.3 -2410.9  
## + volatile.acidity:total.sulfur.dioxide 1 2.811 2100.3 -2410.8  
## + residual.sugar:alcohol 1 2.733 2100.4 -2410.7  
## + pH:sulphates 1 2.724 2100.4 -2410.7  
## + free.sulfur.dioxide:sulphates 1 2.236 2100.9 -2409.7  
## - citric.acid 1 0.113 2103.3 -2409.4  
## - chlorides 1 0.327 2103.5 -2409.0  
## + volatile.acidity:residual.sugar 1 1.481 2101.7 -2408.3  
## + residual.sugar:sulphates 1 1.423 2101.7 -2408.2  
## + chlorides:density 1 1.395 2101.8 -2408.2  
## + density:sulphates 1 1.157 2102.0 -2407.7  
## + fixed.acidity:chlorides 1 1.153 2102.0 -2407.7  
## <none> 2103.1 -2407.6  
## + volatile.acidity:sulphates 1 1.069 2102.1 -2407.6  
## + citric.acid:chlorides 1 1.041 2102.1 -2407.5  
## + volatile.acidity:pH 1 0.995 2102.2 -2407.4  
## + citric.acid:residual.sugar 1 0.968 2102.2 -2407.4  
## + citric.acid:sulphates 1 0.944 2102.2 -2407.3  
## + citric.acid:free.sulfur.dioxide 1 0.896 2102.2 -2407.2  
## + fixed.acidity:sulphates 1 0.861 2102.3 -2407.2  
## + volatile.acidity:free.sulfur.dioxide 1 0.634 2102.5 -2406.8  
## + sulphates:alcohol 1 0.609 2102.5 -2406.7  
## + citric.acid:density 1 0.491 2102.7 -2406.5  
## + chlorides:total.sulfur.dioxide 1 0.322 2102.8 -2406.2  
## + residual.sugar:chlorides 1 0.249 2102.9 -2406.0  
## + total.sulfur.dioxide:alcohol 1 0.237 2102.9 -2406.0  
## + citric.acid:alcohol 1 0.190 2102.9 -2405.9  
## + citric.acid:total.sulfur.dioxide 1 0.177 2103.0 -2405.9  
## + volatile.acidity:chlorides 1 0.163 2103.0 -2405.9  
## + chlorides:free.sulfur.dioxide 1 0.156 2103.0 -2405.9  
## + free.sulfur.dioxide:density 1 0.022 2103.1 -2405.6  
## + fixed.acidity:volatile.acidity 1 0.016 2103.1 -2405.6  
## - fixed.acidity 1 8.616 2111.8 -2393.6  
## - pH 1 18.086 2121.2 -2376.0  
## - sulphates 1 18.104 2121.2 -2376.0  
## - residual.sugar:free.sulfur.dioxide 1 18.566 2121.7 -2375.1  
## - volatile.acidity:alcohol 1 26.418 2129.6 -2360.7  
## - density 1 33.188 2136.3 -2348.2  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 66.541 2169.7 -2287.5  
##   
## Step: AIC=-2434.67  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol  
##   
## Df Sum of Sq RSS AIC  
## + fixed.acidity:citric.acid 1 12.225 2075.4 -2455.7  
## + fixed.acidity:free.sulfur.dioxide 1 9.880 2077.7 -2451.3  
## + fixed.acidity:pH 1 8.580 2079.0 -2448.8  
## + citric.acid:pH 1 8.193 2079.4 -2448.1  
## + fixed.acidity:residual.sugar 1 7.026 2080.6 -2445.9  
## + total.sulfur.dioxide:density 1 5.543 2082.0 -2443.1  
## + residual.sugar:density 1 5.177 2082.4 -2442.4  
## + density:alcohol 1 5.057 2082.5 -2442.2  
## + chlorides:alcohol 1 5.055 2082.5 -2442.2  
## + residual.sugar:total.sulfur.dioxide 1 4.418 2083.2 -2441.0  
## + chlorides:sulphates 1 4.196 2083.4 -2440.6  
## + total.sulfur.dioxide:sulphates 1 3.679 2083.9 -2439.6  
## + total.sulfur.dioxide:pH 1 3.273 2084.3 -2438.8  
## + volatile.acidity:citric.acid 1 3.153 2084.4 -2438.6  
## + volatile.acidity:density 1 2.993 2084.6 -2438.3  
## + volatile.acidity:total.sulfur.dioxide 1 2.828 2084.8 -2438.0  
## + fixed.acidity:total.sulfur.dioxide 1 2.712 2084.9 -2437.8  
## + free.sulfur.dioxide:sulphates 1 2.623 2085.0 -2437.6  
## + free.sulfur.dioxide:alcohol 1 2.553 2085.0 -2437.5  
## + residual.sugar:pH 1 2.485 2085.1 -2437.3  
## + fixed.acidity:density 1 2.270 2085.3 -2436.9  
## + pH:sulphates 1 2.266 2085.3 -2436.9  
## + chlorides:pH 1 2.153 2085.4 -2436.7  
## - citric.acid 1 0.024 2087.6 -2436.6  
## + volatile.acidity:sulphates 1 1.891 2085.7 -2436.2  
## + volatile.acidity:residual.sugar 1 1.758 2085.8 -2436.0  
## + citric.acid:residual.sugar 1 1.596 2086.0 -2435.7  
## - chlorides 1 0.555 2088.1 -2435.6  
## + citric.acid:density 1 1.530 2086.1 -2435.6  
## + residual.sugar:sulphates 1 1.330 2086.2 -2435.2  
## + free.sulfur.dioxide:pH 1 1.264 2086.3 -2435.1  
## + citric.acid:alcohol 1 1.121 2086.5 -2434.8  
## <none> 2087.6 -2434.7  
## + citric.acid:chlorides 1 0.801 2086.8 -2434.2  
## + residual.sugar:alcohol 1 0.728 2086.8 -2434.0  
## + chlorides:density 1 0.706 2086.9 -2434.0  
## + residual.sugar:chlorides 1 0.705 2086.9 -2434.0  
## + fixed.acidity:sulphates 1 0.702 2086.9 -2434.0  
## + citric.acid:sulphates 1 0.642 2086.9 -2433.9  
## + density:sulphates 1 0.637 2086.9 -2433.9  
## + density:pH 1 0.595 2087.0 -2433.8  
## + citric.acid:free.sulfur.dioxide 1 0.550 2087.0 -2433.7  
## + volatile.acidity:free.sulfur.dioxide 1 0.488 2087.1 -2433.6  
## + chlorides:total.sulfur.dioxide 1 0.441 2087.1 -2433.5  
## + citric.acid:total.sulfur.dioxide 1 0.419 2087.2 -2433.5  
## + volatile.acidity:chlorides 1 0.249 2087.3 -2433.1  
## + total.sulfur.dioxide:alcohol 1 0.240 2087.3 -2433.1  
## + fixed.acidity:alcohol 1 0.181 2087.4 -2433.0  
## + volatile.acidity:pH 1 0.163 2087.4 -2433.0  
## + chlorides:free.sulfur.dioxide 1 0.156 2087.4 -2433.0  
## + fixed.acidity:chlorides 1 0.066 2087.5 -2432.8  
## + sulphates:alcohol 1 0.060 2087.5 -2432.8  
## + free.sulfur.dioxide:density 1 0.018 2087.6 -2432.7  
## + fixed.acidity:volatile.acidity 1 0.013 2087.6 -2432.7  
## - fixed.acidity 1 11.252 2098.8 -2415.6  
## - pH:alcohol 1 15.561 2103.1 -2407.6  
## - sulphates 1 17.365 2104.9 -2404.2  
## - residual.sugar:free.sulfur.dioxide 1 18.319 2105.9 -2402.4  
## - volatile.acidity:alcohol 1 23.909 2111.5 -2392.1  
## - density 1 32.031 2119.6 -2377.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 65.866 2153.4 -2315.0  
##   
## Step: AIC=-2455.69  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid  
##   
## Df Sum of Sq RSS AIC  
## + fixed.acidity:free.sulfur.dioxide 1 10.215 2065.1 -2473.0  
## + fixed.acidity:residual.sugar 1 8.510 2066.8 -2469.8  
## + total.sulfur.dioxide:density 1 6.126 2069.2 -2465.3  
## + density:alcohol 1 5.632 2069.7 -2464.3  
## + fixed.acidity:density 1 5.131 2070.2 -2463.4  
## + residual.sugar:total.sulfur.dioxide 1 4.816 2070.5 -2462.8  
## + residual.sugar:density 1 4.745 2070.6 -2462.7  
## + chlorides:alcohol 1 4.600 2070.8 -2462.4  
## + fixed.acidity:total.sulfur.dioxide 1 4.532 2070.8 -2462.2  
## + fixed.acidity:pH 1 3.980 2071.4 -2461.2  
## + total.sulfur.dioxide:pH 1 3.908 2071.4 -2461.1  
## + chlorides:sulphates 1 3.720 2071.6 -2460.7  
## + total.sulfur.dioxide:sulphates 1 2.907 2072.4 -2459.2  
## + volatile.acidity:total.sulfur.dioxide 1 2.852 2072.5 -2459.1  
## + residual.sugar:pH 1 2.665 2072.7 -2458.7  
## + volatile.acidity:density 1 2.575 2072.8 -2458.6  
## + free.sulfur.dioxide:alcohol 1 2.417 2072.9 -2458.2  
## + free.sulfur.dioxide:sulphates 1 2.287 2073.1 -2458.0  
## + chlorides:pH 1 2.175 2073.2 -2457.8  
## + citric.acid:pH 1 2.025 2073.3 -2457.5  
## + volatile.acidity:citric.acid 1 1.839 2073.5 -2457.2  
## + volatile.acidity:residual.sugar 1 1.695 2073.7 -2456.9  
## + pH:sulphates 1 1.523 2073.8 -2456.6  
## + free.sulfur.dioxide:pH 1 1.439 2073.9 -2456.4  
## + volatile.acidity:sulphates 1 1.396 2074.0 -2456.3  
## + density:pH 1 1.319 2074.0 -2456.2  
## - chlorides 1 1.055 2076.4 -2455.7  
## <none> 2075.4 -2455.7  
## + residual.sugar:sulphates 1 0.863 2074.5 -2455.3  
## + residual.sugar:alcohol 1 0.784 2074.6 -2455.2  
## + volatile.acidity:pH 1 0.742 2074.6 -2455.1  
## + residual.sugar:chlorides 1 0.738 2074.6 -2455.1  
## + volatile.acidity:free.sulfur.dioxide 1 0.728 2074.6 -2455.1  
## + citric.acid:alcohol 1 0.723 2074.6 -2455.1  
## + chlorides:density 1 0.672 2074.7 -2454.9  
## + citric.acid:chlorides 1 0.660 2074.7 -2454.9  
## + fixed.acidity:alcohol 1 0.651 2074.7 -2454.9  
## + citric.acid:free.sulfur.dioxide 1 0.629 2074.7 -2454.9  
## + citric.acid:residual.sugar 1 0.523 2074.8 -2454.7  
## + citric.acid:sulphates 1 0.451 2074.9 -2454.5  
## + fixed.acidity:chlorides 1 0.355 2075.0 -2454.4  
## + density:sulphates 1 0.314 2075.0 -2454.3  
## + fixed.acidity:sulphates 1 0.305 2075.1 -2454.3  
## + fixed.acidity:volatile.acidity 1 0.262 2075.1 -2454.2  
## + chlorides:total.sulfur.dioxide 1 0.257 2075.1 -2454.2  
## + volatile.acidity:chlorides 1 0.250 2075.1 -2454.2  
## + total.sulfur.dioxide:alcohol 1 0.215 2075.1 -2454.1  
## + chlorides:free.sulfur.dioxide 1 0.083 2075.3 -2453.8  
## + citric.acid:density 1 0.082 2075.3 -2453.8  
## + citric.acid:total.sulfur.dioxide 1 0.047 2075.3 -2453.8  
## + free.sulfur.dioxide:density 1 0.032 2075.3 -2453.8  
## + sulphates:alcohol 1 0.003 2075.3 -2453.7  
## - fixed.acidity:citric.acid 1 12.225 2087.6 -2434.7  
## - sulphates 1 17.202 2092.6 -2425.3  
## - residual.sugar:free.sulfur.dioxide 1 17.794 2093.2 -2424.2  
## - pH:alcohol 1 18.917 2094.3 -2422.1  
## - volatile.acidity:alcohol 1 25.216 2100.6 -2410.4  
## - density 1 29.149 2104.5 -2403.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 65.026 2140.4 -2336.8  
##   
## Step: AIC=-2473.02  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide  
##   
## Df Sum of Sq RSS AIC  
## + density:alcohol 1 4.880 2060.3 -2480.3  
## + fixed.acidity:residual.sugar 1 4.588 2060.6 -2479.7  
## + residual.sugar:density 1 4.286 2060.9 -2479.2  
## + chlorides:sulphates 1 4.005 2061.1 -2478.6  
## + chlorides:alcohol 1 3.995 2061.2 -2478.6  
## + residual.sugar:total.sulfur.dioxide 1 3.944 2061.2 -2478.5  
## + total.sulfur.dioxide:density 1 3.708 2061.4 -2478.1  
## + free.sulfur.dioxide:alcohol 1 3.455 2061.7 -2477.6  
## + volatile.acidity:total.sulfur.dioxide 1 3.400 2061.7 -2477.5  
## + total.sulfur.dioxide:sulphates 1 3.038 2062.1 -2476.8  
## + fixed.acidity:density 1 2.879 2062.3 -2476.5  
## + free.sulfur.dioxide:sulphates 1 2.812 2062.3 -2476.4  
## + fixed.acidity:pH 1 2.686 2062.5 -2476.1  
## + citric.acid:pH 1 2.545 2062.6 -2475.8  
## + volatile.acidity:density 1 2.460 2062.7 -2475.7  
## + residual.sugar:pH 1 2.059 2063.1 -2474.9  
## + volatile.acidity:citric.acid 1 1.940 2063.2 -2474.7  
## + chlorides:pH 1 1.832 2063.3 -2474.5  
## + pH:sulphates 1 1.724 2063.4 -2474.3  
## + volatile.acidity:residual.sugar 1 1.620 2063.5 -2474.1  
## + volatile.acidity:sulphates 1 1.334 2063.8 -2473.6  
## + citric.acid:alcohol 1 1.260 2063.9 -2473.4  
## + total.sulfur.dioxide:pH 1 1.247 2063.9 -2473.4  
## + residual.sugar:sulphates 1 1.141 2064.0 -2473.2  
## + density:pH 1 1.107 2064.0 -2473.1  
## <none> 2065.1 -2473.0  
## + citric.acid:residual.sugar 1 1.049 2064.1 -2473.0  
## - chlorides 1 1.071 2066.2 -2473.0  
## + free.sulfur.dioxide:density 1 1.015 2064.1 -2472.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.860 2064.3 -2472.7  
## + residual.sugar:alcohol 1 0.685 2064.5 -2472.3  
## + residual.sugar:chlorides 1 0.648 2064.5 -2472.2  
## + fixed.acidity:sulphates 1 0.619 2064.5 -2472.2  
## + chlorides:density 1 0.600 2064.5 -2472.2  
## + citric.acid:total.sulfur.dioxide 1 0.587 2064.6 -2472.1  
## + density:sulphates 1 0.562 2064.6 -2472.1  
## + volatile.acidity:pH 1 0.533 2064.6 -2472.0  
## + citric.acid:sulphates 1 0.402 2064.7 -2471.8  
## + citric.acid:chlorides 1 0.399 2064.7 -2471.8  
## + citric.acid:density 1 0.371 2064.8 -2471.7  
## + volatile.acidity:chlorides 1 0.224 2064.9 -2471.4  
## + chlorides:total.sulfur.dioxide 1 0.218 2064.9 -2471.4  
## + fixed.acidity:alcohol 1 0.166 2065.0 -2471.3  
## + fixed.acidity:chlorides 1 0.148 2065.0 -2471.3  
## + fixed.acidity:volatile.acidity 1 0.094 2065.1 -2471.2  
## + fixed.acidity:total.sulfur.dioxide 1 0.066 2065.1 -2471.1  
## + chlorides:free.sulfur.dioxide 1 0.049 2065.1 -2471.1  
## + sulphates:alcohol 1 0.046 2065.1 -2471.1  
## + total.sulfur.dioxide:alcohol 1 0.034 2065.1 -2471.1  
## + free.sulfur.dioxide:pH 1 0.027 2065.1 -2471.1  
## + citric.acid:free.sulfur.dioxide 1 0.001 2065.1 -2471.0  
## - fixed.acidity:free.sulfur.dioxide 1 10.215 2075.4 -2455.7  
## - fixed.acidity:citric.acid 1 12.560 2077.7 -2451.3  
## - sulphates 1 17.013 2082.2 -2442.9  
## - pH:alcohol 1 17.700 2082.8 -2441.6  
## - residual.sugar:free.sulfur.dioxide 1 22.584 2087.7 -2432.4  
## - volatile.acidity:alcohol 1 24.383 2089.5 -2429.0  
## - density 1 28.782 2093.9 -2420.8  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 57.289 2122.4 -2367.8  
##   
## Step: AIC=-2480.29  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol  
##   
## Df Sum of Sq RSS AIC  
## + volatile.acidity:density 1 5.137 2055.1 -2488.1  
## + free.sulfur.dioxide:alcohol 1 4.564 2055.7 -2487.0  
## + residual.sugar:density 1 4.248 2056.0 -2486.4  
## + chlorides:sulphates 1 4.239 2056.0 -2486.4  
## + fixed.acidity:residual.sugar 1 3.620 2056.6 -2485.2  
## + volatile.acidity:total.sulfur.dioxide 1 3.605 2056.7 -2485.2  
## + volatile.acidity:residual.sugar 1 3.558 2056.7 -2485.1  
## + total.sulfur.dioxide:sulphates 1 3.278 2057.0 -2484.5  
## + residual.sugar:alcohol 1 2.885 2057.4 -2483.8  
## + citric.acid:pH 1 2.883 2057.4 -2483.8  
## + free.sulfur.dioxide:sulphates 1 2.623 2057.6 -2483.3  
## + fixed.acidity:pH 1 2.527 2057.7 -2483.1  
## + residual.sugar:total.sulfur.dioxide 1 2.473 2057.8 -2483.0  
## + free.sulfur.dioxide:density 1 2.325 2057.9 -2482.7  
## + volatile.acidity:citric.acid 1 2.228 2058.0 -2482.5  
## + citric.acid:alcohol 1 2.184 2058.1 -2482.4  
## + chlorides:alcohol 1 1.987 2058.3 -2482.1  
## + pH:sulphates 1 1.867 2058.4 -2481.8  
## + chlorides:pH 1 1.809 2058.4 -2481.7  
## + total.sulfur.dioxide:density 1 1.528 2058.7 -2481.2  
## + fixed.acidity:density 1 1.481 2058.8 -2481.1  
## + residual.sugar:chlorides 1 1.468 2058.8 -2481.1  
## + residual.sugar:pH 1 1.415 2058.8 -2481.0  
## + volatile.acidity:sulphates 1 1.300 2059.0 -2480.8  
## + total.sulfur.dioxide:pH 1 1.146 2059.1 -2480.5  
## + residual.sugar:sulphates 1 1.084 2059.2 -2480.3  
## <none> 2060.3 -2480.3  
## - chlorides 1 1.141 2061.4 -2480.1  
## + citric.acid:residual.sugar 1 0.869 2059.4 -2479.9  
## + fixed.acidity:sulphates 1 0.816 2059.4 -2479.8  
## + volatile.acidity:free.sulfur.dioxide 1 0.687 2059.6 -2479.6  
## + citric.acid:total.sulfur.dioxide 1 0.682 2059.6 -2479.6  
## + volatile.acidity:pH 1 0.670 2059.6 -2479.6  
## + total.sulfur.dioxide:alcohol 1 0.624 2059.6 -2479.5  
## + density:pH 1 0.552 2059.7 -2479.3  
## + chlorides:total.sulfur.dioxide 1 0.529 2059.7 -2479.3  
## + citric.acid:chlorides 1 0.476 2059.8 -2479.2  
## + density:sulphates 1 0.464 2059.8 -2479.2  
## + citric.acid:sulphates 1 0.432 2059.8 -2479.1  
## + citric.acid:density 1 0.325 2059.9 -2478.9  
## + volatile.acidity:chlorides 1 0.300 2060.0 -2478.9  
## + fixed.acidity:alcohol 1 0.140 2060.1 -2478.6  
## + sulphates:alcohol 1 0.069 2060.2 -2478.4  
## + chlorides:density 1 0.062 2060.2 -2478.4  
## + chlorides:free.sulfur.dioxide 1 0.052 2060.2 -2478.4  
## + fixed.acidity:volatile.acidity 1 0.036 2060.2 -2478.4  
## + citric.acid:free.sulfur.dioxide 1 0.013 2060.2 -2478.3  
## + fixed.acidity:chlorides 1 0.002 2060.3 -2478.3  
## + free.sulfur.dioxide:pH 1 0.001 2060.3 -2478.3  
## + fixed.acidity:total.sulfur.dioxide 1 0.000 2060.3 -2478.3  
## - density:alcohol 1 4.880 2065.1 -2473.0  
## - fixed.acidity:free.sulfur.dioxide 1 9.464 2069.7 -2464.3  
## - fixed.acidity:citric.acid 1 13.090 2073.3 -2457.5  
## - pH:alcohol 1 14.993 2075.2 -2453.9  
## - sulphates 1 15.935 2076.2 -2452.1  
## - volatile.acidity:alcohol 1 21.972 2082.2 -2440.7  
## - residual.sugar:free.sulfur.dioxide 1 26.235 2086.5 -2432.7  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 57.431 2117.7 -2374.6  
##   
## Step: AIC=-2488.07  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density  
##   
## Df Sum of Sq RSS AIC  
## + free.sulfur.dioxide:alcohol 1 6.159 2049.0 -2497.8  
## + chlorides:sulphates 1 4.710 2050.4 -2495.1  
## + residual.sugar:chlorides 1 3.782 2051.3 -2493.3  
## + total.sulfur.dioxide:sulphates 1 3.430 2051.7 -2492.6  
## + residual.sugar:sulphates 1 3.201 2051.9 -2492.2  
## + residual.sugar:alcohol 1 3.105 2052.0 -2492.0  
## + free.sulfur.dioxide:sulphates 1 2.846 2052.3 -2491.5  
## + residual.sugar:pH 1 2.840 2052.3 -2491.5  
## + fixed.acidity:pH 1 2.767 2052.4 -2491.3  
## + citric.acid:pH 1 2.748 2052.4 -2491.3  
## + volatile.acidity:sulphates 1 2.598 2052.5 -2491.0  
## + citric.acid:residual.sugar 1 2.390 2052.7 -2490.6  
## + citric.acid:alcohol 1 2.295 2052.8 -2490.4  
## + fixed.acidity:residual.sugar 1 2.279 2052.8 -2490.4  
## + citric.acid:density 1 2.234 2052.9 -2490.3  
## + pH:sulphates 1 2.133 2053.0 -2490.1  
## + density:pH 1 2.010 2053.1 -2489.9  
## + density:sulphates 1 1.936 2053.2 -2489.8  
## + volatile.acidity:total.sulfur.dioxide 1 1.701 2053.4 -2489.3  
## + chlorides:pH 1 1.681 2053.4 -2489.3  
## + chlorides:alcohol 1 1.668 2053.5 -2489.2  
## + free.sulfur.dioxide:density 1 1.349 2053.8 -2488.6  
## + total.sulfur.dioxide:alcohol 1 1.343 2053.8 -2488.6  
## - chlorides 1 0.804 2055.9 -2488.5  
## <none> 2055.1 -2488.1  
## + fixed.acidity:sulphates 1 0.895 2054.2 -2487.8  
## + volatile.acidity:chlorides 1 0.873 2054.2 -2487.7  
## + chlorides:total.sulfur.dioxide 1 0.845 2054.3 -2487.7  
## + total.sulfur.dioxide:pH 1 0.840 2054.3 -2487.7  
## + volatile.acidity:citric.acid 1 0.827 2054.3 -2487.7  
## + citric.acid:total.sulfur.dioxide 1 0.817 2054.3 -2487.6  
## + volatile.acidity:pH 1 0.590 2054.5 -2487.2  
## + residual.sugar:total.sulfur.dioxide 1 0.546 2054.6 -2487.1  
## + volatile.acidity:free.sulfur.dioxide 1 0.536 2054.6 -2487.1  
## + citric.acid:sulphates 1 0.509 2054.6 -2487.0  
## + fixed.acidity:density 1 0.483 2054.6 -2487.0  
## + fixed.acidity:volatile.acidity 1 0.455 2054.7 -2486.9  
## + chlorides:density 1 0.439 2054.7 -2486.9  
## + citric.acid:chlorides 1 0.425 2054.7 -2486.9  
## + fixed.acidity:alcohol 1 0.266 2054.9 -2486.6  
## + total.sulfur.dioxide:density 1 0.131 2055.0 -2486.3  
## + volatile.acidity:residual.sugar 1 0.130 2055.0 -2486.3  
## + sulphates:alcohol 1 0.080 2055.1 -2486.2  
## + residual.sugar:density 1 0.063 2055.1 -2486.2  
## + chlorides:free.sulfur.dioxide 1 0.060 2055.1 -2486.2  
## + free.sulfur.dioxide:pH 1 0.022 2055.1 -2486.1  
## + fixed.acidity:total.sulfur.dioxide 1 0.007 2055.1 -2486.1  
## + citric.acid:free.sulfur.dioxide 1 0.007 2055.1 -2486.1  
## + fixed.acidity:chlorides 1 0.006 2055.1 -2486.1  
## - volatile.acidity:density 1 5.137 2060.3 -2480.3  
## - density:alcohol 1 7.557 2062.7 -2475.7  
## - fixed.acidity:free.sulfur.dioxide 1 9.088 2064.2 -2472.8  
## - fixed.acidity:citric.acid 1 12.626 2067.8 -2466.1  
## - pH:alcohol 1 14.135 2069.3 -2463.2  
## - sulphates 1 17.671 2072.8 -2456.5  
## - residual.sugar:free.sulfur.dioxide 1 18.889 2074.0 -2454.2  
## - volatile.acidity:alcohol 1 27.086 2082.2 -2438.8  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 57.459 2112.6 -2382.0  
##   
## Step: AIC=-2497.83  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol  
##   
## Df Sum of Sq RSS AIC  
## + chlorides:sulphates 1 5.669 2043.3 -2506.7  
## + residual.sugar:chlorides 1 4.430 2044.5 -2504.3  
## + total.sulfur.dioxide:sulphates 1 3.898 2045.1 -2503.3  
## + residual.sugar:sulphates 1 3.527 2045.4 -2502.6  
## + residual.sugar:alcohol 1 3.089 2045.9 -2501.7  
## + free.sulfur.dioxide:density 1 2.944 2046.0 -2501.5  
## + fixed.acidity:pH 1 2.860 2046.1 -2501.3  
## + residual.sugar:pH 1 2.779 2046.2 -2501.1  
## + citric.acid:residual.sugar 1 2.626 2046.3 -2500.8  
## + volatile.acidity:sulphates 1 2.388 2046.6 -2500.4  
## + citric.acid:pH 1 2.378 2046.6 -2500.4  
## + pH:sulphates 1 2.336 2046.6 -2500.3  
## + chlorides:alcohol 1 2.297 2046.7 -2500.2  
## + density:sulphates 1 2.274 2046.7 -2500.2  
## + citric.acid:density 1 2.140 2046.8 -2499.9  
## + fixed.acidity:residual.sugar 1 1.956 2047.0 -2499.6  
## + density:pH 1 1.925 2047.0 -2499.5  
## + free.sulfur.dioxide:sulphates 1 1.919 2047.0 -2499.5  
## + chlorides:pH 1 1.824 2047.1 -2499.3  
## + citric.acid:alcohol 1 1.680 2047.3 -2499.0  
## - chlorides 1 0.619 2049.6 -2498.6  
## + volatile.acidity:total.sulfur.dioxide 1 1.467 2047.5 -2498.6  
## + volatile.acidity:chlorides 1 1.079 2047.9 -2497.9  
## <none> 2049.0 -2497.8  
## + total.sulfur.dioxide:pH 1 0.951 2048.0 -2497.7  
## + volatile.acidity:citric.acid 1 0.896 2048.1 -2497.5  
## + citric.acid:total.sulfur.dioxide 1 0.876 2048.1 -2497.5  
## + fixed.acidity:sulphates 1 0.838 2048.1 -2497.4  
## + total.sulfur.dioxide:density 1 0.742 2048.2 -2497.2  
## + citric.acid:sulphates 1 0.726 2048.2 -2497.2  
## + fixed.acidity:alcohol 1 0.606 2048.4 -2497.0  
## + citric.acid:chlorides 1 0.599 2048.4 -2497.0  
## + chlorides:density 1 0.545 2048.4 -2496.9  
## + volatile.acidity:pH 1 0.482 2048.5 -2496.8  
## + fixed.acidity:volatile.acidity 1 0.473 2048.5 -2496.7  
## + volatile.acidity:free.sulfur.dioxide 1 0.463 2048.5 -2496.7  
## + chlorides:total.sulfur.dioxide 1 0.329 2048.6 -2496.5  
## + chlorides:free.sulfur.dioxide 1 0.309 2048.7 -2496.4  
## + residual.sugar:total.sulfur.dioxide 1 0.292 2048.7 -2496.4  
## + sulphates:alcohol 1 0.227 2048.7 -2496.3  
## + fixed.acidity:density 1 0.185 2048.8 -2496.2  
## + volatile.acidity:residual.sugar 1 0.068 2048.9 -2496.0  
## + fixed.acidity:total.sulfur.dioxide 1 0.057 2048.9 -2495.9  
## + fixed.acidity:chlorides 1 0.031 2048.9 -2495.9  
## + total.sulfur.dioxide:alcohol 1 0.022 2048.9 -2495.9  
## + free.sulfur.dioxide:pH 1 0.013 2048.9 -2495.8  
## + citric.acid:free.sulfur.dioxide 1 0.005 2049.0 -2495.8  
## + residual.sugar:density 1 0.000 2049.0 -2495.8  
## - free.sulfur.dioxide:alcohol 1 6.159 2055.1 -2488.1  
## - volatile.acidity:density 1 6.731 2055.7 -2487.0  
## - residual.sugar:free.sulfur.dioxide 1 9.045 2058.0 -2482.6  
## - density:alcohol 1 9.596 2058.6 -2481.5  
## - fixed.acidity:free.sulfur.dioxide 1 10.320 2059.3 -2480.1  
## - fixed.acidity:citric.acid 1 12.431 2061.4 -2476.1  
## - pH:alcohol 1 13.172 2062.1 -2474.7  
## - sulphates 1 17.713 2066.7 -2466.1  
## - volatile.acidity:alcohol 1 31.203 2080.2 -2440.6  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 46.226 2095.2 -2412.4  
##   
## Step: AIC=-2506.68  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates  
##   
## Df Sum of Sq RSS AIC  
## + residual.sugar:pH 1 3.301 2040.0 -2511.0  
## + free.sulfur.dioxide:density 1 3.293 2040.0 -2511.0  
## + residual.sugar:alcohol 1 2.985 2040.3 -2510.4  
## + residual.sugar:chlorides 1 2.665 2040.6 -2509.8  
## + free.sulfur.dioxide:sulphates 1 2.624 2040.7 -2509.7  
## + fixed.acidity:pH 1 2.579 2040.7 -2509.6  
## + citric.acid:pH 1 2.575 2040.7 -2509.6  
## + residual.sugar:sulphates 1 2.554 2040.7 -2509.6  
## + chlorides:alcohol 1 2.395 2040.9 -2509.3  
## + pH:sulphates 1 2.226 2041.1 -2508.9  
## + density:pH 1 2.181 2041.1 -2508.9  
## + total.sulfur.dioxide:sulphates 1 2.100 2041.2 -2508.7  
## + chlorides:pH 1 2.087 2041.2 -2508.7  
## + volatile.acidity:sulphates 1 2.057 2041.2 -2508.6  
## + citric.acid:residual.sugar 1 2.040 2041.3 -2508.6  
## + fixed.acidity:residual.sugar 1 1.978 2041.3 -2508.5  
## + citric.acid:alcohol 1 1.928 2041.4 -2508.4  
## + volatile.acidity:total.sulfur.dioxide 1 1.865 2041.4 -2508.3  
## + citric.acid:density 1 1.816 2041.5 -2508.2  
## + volatile.acidity:citric.acid 1 1.208 2042.1 -2507.0  
## + total.sulfur.dioxide:density 1 1.121 2042.2 -2506.8  
## <none> 2043.3 -2506.7  
## + total.sulfur.dioxide:pH 1 0.999 2042.3 -2506.6  
## + citric.acid:total.sulfur.dioxide 1 0.743 2042.5 -2506.1  
## + density:sulphates 1 0.661 2042.6 -2505.9  
## + fixed.acidity:alcohol 1 0.578 2042.7 -2505.8  
## + fixed.acidity:sulphates 1 0.533 2042.8 -2505.7  
## + fixed.acidity:volatile.acidity 1 0.479 2042.8 -2505.6  
## + volatile.acidity:free.sulfur.dioxide 1 0.465 2042.8 -2505.6  
## + residual.sugar:total.sulfur.dioxide 1 0.332 2043.0 -2505.3  
## + volatile.acidity:pH 1 0.256 2043.0 -2505.2  
## + citric.acid:sulphates 1 0.255 2043.0 -2505.2  
## + sulphates:alcohol 1 0.233 2043.1 -2505.1  
## + fixed.acidity:density 1 0.197 2043.1 -2505.1  
## + total.sulfur.dioxide:alcohol 1 0.153 2043.1 -2505.0  
## + citric.acid:chlorides 1 0.108 2043.2 -2504.9  
## + fixed.acidity:chlorides 1 0.100 2043.2 -2504.9  
## + fixed.acidity:total.sulfur.dioxide 1 0.070 2043.2 -2504.8  
## + volatile.acidity:residual.sugar 1 0.063 2043.2 -2504.8  
## + volatile.acidity:chlorides 1 0.054 2043.2 -2504.8  
## + chlorides:total.sulfur.dioxide 1 0.016 2043.3 -2504.7  
## + residual.sugar:density 1 0.003 2043.3 -2504.7  
## + chlorides:density 1 0.002 2043.3 -2504.7  
## + citric.acid:free.sulfur.dioxide 1 0.001 2043.3 -2504.7  
## + chlorides:free.sulfur.dioxide 1 0.001 2043.3 -2504.7  
## + free.sulfur.dioxide:pH 1 0.001 2043.3 -2504.7  
## - chlorides:sulphates 1 5.669 2049.0 -2497.8  
## - free.sulfur.dioxide:alcohol 1 7.118 2050.4 -2495.1  
## - volatile.acidity:density 1 7.458 2050.8 -2494.4  
## - residual.sugar:free.sulfur.dioxide 1 8.442 2051.7 -2492.5  
## - density:alcohol 1 10.328 2053.6 -2488.9  
## - fixed.acidity:free.sulfur.dioxide 1 10.726 2054.0 -2488.2  
## - fixed.acidity:citric.acid 1 11.822 2055.1 -2486.1  
## - pH:alcohol 1 12.258 2055.6 -2485.2  
## - volatile.acidity:alcohol 1 30.145 2073.4 -2451.3  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 44.615 2087.9 -2424.1  
##   
## Step: AIC=-2511.02  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH  
##   
## Df Sum of Sq RSS AIC  
## + free.sulfur.dioxide:density 1 3.954 2036.0 -2516.6  
## + residual.sugar:alcohol 1 3.629 2036.4 -2516.0  
## + citric.acid:pH 1 3.554 2036.4 -2515.8  
## + residual.sugar:chlorides 1 3.045 2037.0 -2514.9  
## + fixed.acidity:pH 1 2.762 2037.2 -2514.3  
## + citric.acid:residual.sugar 1 2.739 2037.3 -2514.3  
## + chlorides:alcohol 1 2.660 2037.3 -2514.1  
## + free.sulfur.dioxide:sulphates 1 2.641 2037.4 -2514.1  
## + chlorides:pH 1 2.228 2037.8 -2513.3  
## + citric.acid:density 1 2.072 2037.9 -2513.0  
## + volatile.acidity:sulphates 1 2.048 2038.0 -2512.9  
## + total.sulfur.dioxide:sulphates 1 2.043 2038.0 -2512.9  
## + citric.acid:alcohol 1 1.947 2038.0 -2512.8  
## + pH:sulphates 1 1.917 2038.1 -2512.7  
## + residual.sugar:sulphates 1 1.879 2038.1 -2512.6  
## + volatile.acidity:total.sulfur.dioxide 1 1.701 2038.3 -2512.3  
## <none> 2040.0 -2511.0  
## + total.sulfur.dioxide:density 1 1.016 2039.0 -2511.0  
## + volatile.acidity:citric.acid 1 0.959 2039.0 -2510.9  
## + citric.acid:total.sulfur.dioxide 1 0.931 2039.1 -2510.8  
## + fixed.acidity:volatile.acidity 1 0.823 2039.2 -2510.6  
## + fixed.acidity:residual.sugar 1 0.755 2039.2 -2510.5  
## + volatile.acidity:pH 1 0.587 2039.4 -2510.1  
## + density:sulphates 1 0.485 2039.5 -2509.9  
## + fixed.acidity:sulphates 1 0.476 2039.5 -2509.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.345 2039.7 -2509.7  
## + fixed.acidity:alcohol 1 0.293 2039.7 -2509.6  
## + total.sulfur.dioxide:pH 1 0.266 2039.7 -2509.5  
## + citric.acid:sulphates 1 0.253 2039.7 -2509.5  
## + residual.sugar:total.sulfur.dioxide 1 0.246 2039.8 -2509.5  
## + fixed.acidity:total.sulfur.dioxide 1 0.215 2039.8 -2509.4  
## + citric.acid:chlorides 1 0.170 2039.8 -2509.3  
## + sulphates:alcohol 1 0.169 2039.8 -2509.3  
## + volatile.acidity:residual.sugar 1 0.134 2039.9 -2509.3  
## + free.sulfur.dioxide:pH 1 0.120 2039.9 -2509.2  
## + fixed.acidity:chlorides 1 0.110 2039.9 -2509.2  
## + total.sulfur.dioxide:alcohol 1 0.068 2039.9 -2509.2  
## + fixed.acidity:density 1 0.050 2040.0 -2509.1  
## + volatile.acidity:chlorides 1 0.033 2040.0 -2509.1  
## + residual.sugar:density 1 0.009 2040.0 -2509.0  
## + chlorides:density 1 0.007 2040.0 -2509.0  
## + density:pH 1 0.002 2040.0 -2509.0  
## + chlorides:total.sulfur.dioxide 1 0.001 2040.0 -2509.0  
## + chlorides:free.sulfur.dioxide 1 0.001 2040.0 -2509.0  
## + citric.acid:free.sulfur.dioxide 1 0.000 2040.0 -2509.0  
## - residual.sugar:pH 1 3.301 2043.3 -2506.7  
## - pH:alcohol 1 5.939 2045.9 -2501.6  
## - chlorides:sulphates 1 6.191 2046.2 -2501.1  
## - free.sulfur.dioxide:alcohol 1 7.095 2047.1 -2499.4  
## - residual.sugar:free.sulfur.dioxide 1 7.566 2047.6 -2498.5  
## - volatile.acidity:density 1 9.264 2049.3 -2495.3  
## - density:alcohol 1 9.686 2049.7 -2494.5  
## - fixed.acidity:free.sulfur.dioxide 1 9.955 2049.9 -2493.9  
## - fixed.acidity:citric.acid 1 11.866 2051.9 -2490.3  
## - volatile.acidity:alcohol 1 31.713 2071.7 -2452.6  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.278 2085.3 -2427.0  
##   
## Step: AIC=-2516.62  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density  
##   
## Df Sum of Sq RSS AIC  
## + citric.acid:pH 1 3.469 2032.6 -2521.3  
## + total.sulfur.dioxide:sulphates 1 3.397 2032.7 -2521.2  
## + fixed.acidity:pH 1 3.279 2032.8 -2520.9  
## + residual.sugar:alcohol 1 3.203 2032.8 -2520.8  
## + residual.sugar:chlorides 1 3.199 2032.8 -2520.8  
## + citric.acid:residual.sugar 1 2.878 2033.2 -2520.2  
## + chlorides:alcohol 1 2.538 2033.5 -2519.5  
## + chlorides:pH 1 2.256 2033.8 -2519.0  
## + citric.acid:density 1 2.095 2034.0 -2518.7  
## + residual.sugar:sulphates 1 2.023 2034.0 -2518.5  
## + citric.acid:alcohol 1 1.974 2034.1 -2518.4  
## + volatile.acidity:sulphates 1 1.954 2034.1 -2518.4  
## + total.sulfur.dioxide:pH 1 1.569 2034.5 -2517.6  
## + fixed.acidity:volatile.acidity 1 1.454 2034.6 -2517.4  
## + pH:sulphates 1 1.446 2034.6 -2517.4  
## + free.sulfur.dioxide:pH 1 1.335 2034.7 -2517.2  
## + free.sulfur.dioxide:sulphates 1 1.249 2034.8 -2517.0  
## + volatile.acidity:total.sulfur.dioxide 1 1.117 2034.9 -2516.8  
## + volatile.acidity:pH 1 1.076 2035.0 -2516.7  
## + citric.acid:total.sulfur.dioxide 1 1.046 2035.0 -2516.6  
## <none> 2036.0 -2516.6  
## + volatile.acidity:citric.acid 1 0.680 2035.4 -2515.9  
## + density:sulphates 1 0.612 2035.4 -2515.8  
## + fixed.acidity:residual.sugar 1 0.511 2035.5 -2515.6  
## + volatile.acidity:residual.sugar 1 0.407 2035.6 -2515.4  
## + total.sulfur.dioxide:density 1 0.396 2035.7 -2515.4  
## + fixed.acidity:sulphates 1 0.367 2035.7 -2515.3  
## + fixed.acidity:alcohol 1 0.302 2035.7 -2515.2  
## + volatile.acidity:free.sulfur.dioxide 1 0.229 2035.8 -2515.1  
## + citric.acid:sulphates 1 0.227 2035.8 -2515.1  
## + residual.sugar:total.sulfur.dioxide 1 0.219 2035.8 -2515.0  
## + citric.acid:chlorides 1 0.198 2035.8 -2515.0  
## + fixed.acidity:total.sulfur.dioxide 1 0.188 2035.9 -2515.0  
## + fixed.acidity:chlorides 1 0.122 2035.9 -2514.8  
## + total.sulfur.dioxide:alcohol 1 0.104 2035.9 -2514.8  
## + sulphates:alcohol 1 0.080 2036.0 -2514.8  
## + residual.sugar:density 1 0.064 2036.0 -2514.7  
## + chlorides:density 1 0.027 2036.0 -2514.7  
## + fixed.acidity:density 1 0.023 2036.0 -2514.7  
## + chlorides:free.sulfur.dioxide 1 0.017 2036.0 -2514.7  
## + volatile.acidity:chlorides 1 0.015 2036.0 -2514.7  
## + chlorides:total.sulfur.dioxide 1 0.014 2036.0 -2514.6  
## + citric.acid:free.sulfur.dioxide 1 0.007 2036.0 -2514.6  
## + density:pH 1 0.006 2036.0 -2514.6  
## - fixed.acidity:free.sulfur.dioxide 1 3.002 2039.0 -2512.8  
## - free.sulfur.dioxide:density 1 3.954 2040.0 -2511.0  
## - residual.sugar:pH 1 3.961 2040.0 -2511.0  
## - chlorides:sulphates 1 6.646 2042.7 -2505.8  
## - pH:alcohol 1 6.787 2042.8 -2505.6  
## - density:alcohol 1 8.724 2044.8 -2501.9  
## - residual.sugar:free.sulfur.dioxide 1 8.804 2044.8 -2501.7  
## - free.sulfur.dioxide:alcohol 1 9.673 2045.7 -2500.1  
## - fixed.acidity:citric.acid 1 11.499 2047.5 -2496.6  
## - volatile.acidity:density 1 13.131 2049.2 -2493.4  
## - volatile.acidity:alcohol 1 35.553 2071.6 -2450.8  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 49.105 2085.2 -2425.2  
##   
## Step: AIC=-2521.3  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH  
##   
## Df Sum of Sq RSS AIC  
## + residual.sugar:chlorides 1 3.655 2028.9 -2526.3  
## + residual.sugar:alcohol 1 3.377 2029.2 -2525.8  
## + total.sulfur.dioxide:sulphates 1 3.306 2029.3 -2525.7  
## + chlorides:alcohol 1 2.657 2029.9 -2524.4  
## + citric.acid:residual.sugar 1 2.430 2030.1 -2524.0  
## + chlorides:pH 1 2.423 2030.2 -2524.0  
## + residual.sugar:sulphates 1 2.090 2030.5 -2523.3  
## + fixed.acidity:pH 1 1.992 2030.6 -2523.1  
## + volatile.acidity:pH 1 1.822 2030.8 -2522.8  
## + free.sulfur.dioxide:pH 1 1.813 2030.8 -2522.8  
## + citric.acid:density 1 1.779 2030.8 -2522.7  
## + fixed.acidity:volatile.acidity 1 1.701 2030.9 -2522.6  
## + total.sulfur.dioxide:pH 1 1.616 2031.0 -2522.4  
## + volatile.acidity:sulphates 1 1.587 2031.0 -2522.4  
## + pH:sulphates 1 1.310 2031.3 -2521.8  
## + volatile.acidity:total.sulfur.dioxide 1 1.305 2031.3 -2521.8  
## + citric.acid:total.sulfur.dioxide 1 1.217 2031.4 -2521.6  
## + free.sulfur.dioxide:sulphates 1 1.076 2031.5 -2521.4  
## <none> 2032.6 -2521.3  
## + citric.acid:chlorides 1 0.838 2031.7 -2520.9  
## + density:sulphates 1 0.715 2031.9 -2520.7  
## + citric.acid:sulphates 1 0.590 2032.0 -2520.4  
## + citric.acid:alcohol 1 0.575 2032.0 -2520.4  
## + volatile.acidity:citric.acid 1 0.554 2032.0 -2520.4  
## + fixed.acidity:sulphates 1 0.439 2032.1 -2520.1  
## + volatile.acidity:residual.sugar 1 0.419 2032.2 -2520.1  
## + fixed.acidity:residual.sugar 1 0.415 2032.2 -2520.1  
## + total.sulfur.dioxide:density 1 0.388 2032.2 -2520.1  
## + fixed.acidity:total.sulfur.dioxide 1 0.321 2032.2 -2519.9  
## + fixed.acidity:alcohol 1 0.258 2032.3 -2519.8  
## + residual.sugar:total.sulfur.dioxide 1 0.245 2032.3 -2519.8  
## + volatile.acidity:free.sulfur.dioxide 1 0.241 2032.3 -2519.8  
## + total.sulfur.dioxide:alcohol 1 0.080 2032.5 -2519.4  
## + fixed.acidity:chlorides 1 0.076 2032.5 -2519.4  
## + chlorides:density 1 0.068 2032.5 -2519.4  
## + sulphates:alcohol 1 0.050 2032.5 -2519.4  
## + chlorides:total.sulfur.dioxide 1 0.047 2032.5 -2519.4  
## + density:pH 1 0.042 2032.5 -2519.4  
## + residual.sugar:density 1 0.028 2032.5 -2519.3  
## + volatile.acidity:chlorides 1 0.014 2032.6 -2519.3  
## + chlorides:free.sulfur.dioxide 1 0.014 2032.6 -2519.3  
## + citric.acid:free.sulfur.dioxide 1 0.012 2032.6 -2519.3  
## + fixed.acidity:density 1 0.000 2032.6 -2519.3  
## - fixed.acidity:free.sulfur.dioxide 1 3.259 2035.8 -2517.0  
## - citric.acid:pH 1 3.469 2036.0 -2516.6  
## - free.sulfur.dioxide:density 1 3.869 2036.4 -2515.8  
## - fixed.acidity:citric.acid 1 4.660 2037.2 -2514.3  
## - residual.sugar:pH 1 4.993 2037.6 -2513.7  
## - pH:alcohol 1 6.866 2039.4 -2510.1  
## - chlorides:sulphates 1 6.974 2039.5 -2509.9  
## - residual.sugar:free.sulfur.dioxide 1 8.884 2041.5 -2506.2  
## - density:alcohol 1 9.006 2041.6 -2506.0  
## - free.sulfur.dioxide:alcohol 1 9.269 2041.8 -2505.5  
## - volatile.acidity:density 1 13.139 2045.7 -2498.1  
## - volatile.acidity:alcohol 1 35.222 2067.8 -2456.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 48.619 2081.2 -2430.7  
##   
## Step: AIC=-2526.35  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides  
##   
## Df Sum of Sq RSS AIC  
## + chlorides:density 1 5.787 2023.1 -2535.5  
## + total.sulfur.dioxide:sulphates 1 3.536 2025.4 -2531.2  
## + chlorides:pH 1 3.475 2025.4 -2531.1  
## + chlorides:alcohol 1 3.440 2025.5 -2531.0  
## + residual.sugar:alcohol 1 2.339 2026.6 -2528.9  
## + residual.sugar:sulphates 1 2.176 2026.7 -2528.6  
## + fixed.acidity:volatile.acidity 1 2.080 2026.8 -2528.4  
## + citric.acid:residual.sugar 1 1.988 2026.9 -2528.2  
## + total.sulfur.dioxide:pH 1 1.978 2026.9 -2528.2  
## + free.sulfur.dioxide:pH 1 1.801 2027.1 -2527.8  
## + fixed.acidity:pH 1 1.792 2027.1 -2527.8  
## + volatile.acidity:pH 1 1.690 2027.2 -2527.6  
## + volatile.acidity:sulphates 1 1.595 2027.3 -2527.4  
## + citric.acid:density 1 1.564 2027.3 -2527.4  
## + volatile.acidity:total.sulfur.dioxide 1 1.303 2027.6 -2526.9  
## + pH:sulphates 1 1.162 2027.8 -2526.6  
## + volatile.acidity:chlorides 1 1.143 2027.8 -2526.6  
## <none> 2028.9 -2526.3  
## + free.sulfur.dioxide:sulphates 1 0.943 2028.0 -2526.2  
## + citric.acid:total.sulfur.dioxide 1 0.903 2028.0 -2526.1  
## + density:sulphates 1 0.881 2028.0 -2526.1  
## + citric.acid:alcohol 1 0.718 2028.2 -2525.7  
## + chlorides:total.sulfur.dioxide 1 0.588 2028.3 -2525.5  
## + volatile.acidity:citric.acid 1 0.579 2028.3 -2525.5  
## + total.sulfur.dioxide:density 1 0.565 2028.3 -2525.4  
## + fixed.acidity:chlorides 1 0.563 2028.4 -2525.4  
## + citric.acid:sulphates 1 0.479 2028.4 -2525.3  
## + fixed.acidity:sulphates 1 0.456 2028.5 -2525.2  
## + residual.sugar:total.sulfur.dioxide 1 0.423 2028.5 -2525.2  
## + volatile.acidity:residual.sugar 1 0.378 2028.5 -2525.1  
## + citric.acid:chlorides 1 0.346 2028.6 -2525.0  
## + fixed.acidity:residual.sugar 1 0.333 2028.6 -2525.0  
## + fixed.acidity:total.sulfur.dioxide 1 0.326 2028.6 -2525.0  
## + fixed.acidity:alcohol 1 0.254 2028.7 -2524.8  
## + volatile.acidity:free.sulfur.dioxide 1 0.166 2028.8 -2524.7  
## + total.sulfur.dioxide:alcohol 1 0.123 2028.8 -2524.6  
## + residual.sugar:density 1 0.099 2028.8 -2524.5  
## + density:pH 1 0.073 2028.8 -2524.5  
## + chlorides:free.sulfur.dioxide 1 0.031 2028.9 -2524.4  
## + sulphates:alcohol 1 0.009 2028.9 -2524.4  
## + citric.acid:free.sulfur.dioxide 1 0.006 2028.9 -2524.4  
## + fixed.acidity:density 1 0.004 2028.9 -2524.4  
## - fixed.acidity:free.sulfur.dioxide 1 2.959 2031.9 -2522.6  
## - residual.sugar:chlorides 1 3.655 2032.6 -2521.3  
## - citric.acid:pH 1 3.925 2032.8 -2520.8  
## - free.sulfur.dioxide:density 1 4.028 2033.0 -2520.6  
## - fixed.acidity:citric.acid 1 4.494 2033.4 -2519.7  
## - chlorides:sulphates 1 4.777 2033.7 -2519.1  
## - residual.sugar:pH 1 5.587 2034.5 -2517.6  
## - pH:alcohol 1 7.194 2036.1 -2514.5  
## - residual.sugar:free.sulfur.dioxide 1 8.826 2037.7 -2511.3  
## - free.sulfur.dioxide:alcohol 1 9.738 2038.7 -2509.6  
## - density:alcohol 1 11.463 2040.4 -2506.3  
## - volatile.acidity:density 1 16.052 2045.0 -2497.5  
## - volatile.acidity:alcohol 1 36.222 2065.1 -2459.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 48.431 2077.3 -2435.9  
##   
## Step: AIC=-2535.54  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density  
##   
## Df Sum of Sq RSS AIC  
## + total.sulfur.dioxide:sulphates 1 3.812 2019.3 -2540.9  
## + chlorides:pH 1 3.060 2020.1 -2539.5  
## + residual.sugar:sulphates 1 2.398 2020.7 -2538.2  
## + fixed.acidity:pH 1 2.140 2021.0 -2537.7  
## + citric.acid:residual.sugar 1 1.970 2021.2 -2537.4  
## + fixed.acidity:volatile.acidity 1 1.920 2021.2 -2537.3  
## + total.sulfur.dioxide:pH 1 1.866 2021.3 -2537.2  
## + citric.acid:density 1 1.819 2021.3 -2537.1  
## + volatile.acidity:pH 1 1.704 2021.4 -2536.8  
## + free.sulfur.dioxide:pH 1 1.627 2021.5 -2536.7  
## + volatile.acidity:sulphates 1 1.481 2021.7 -2536.4  
## + volatile.acidity:total.sulfur.dioxide 1 1.242 2021.9 -2535.9  
## + density:sulphates 1 1.092 2022.0 -2535.7  
## <none> 2023.1 -2535.5  
## + pH:sulphates 1 1.021 2022.1 -2535.5  
## + free.sulfur.dioxide:sulphates 1 1.016 2022.1 -2535.5  
## + citric.acid:total.sulfur.dioxide 1 1.010 2022.1 -2535.5  
## + citric.acid:alcohol 1 0.961 2022.2 -2535.4  
## + residual.sugar:alcohol 1 0.854 2022.3 -2535.2  
## + volatile.acidity:citric.acid 1 0.692 2022.4 -2534.9  
## + fixed.acidity:alcohol 1 0.610 2022.5 -2534.7  
## + fixed.acidity:sulphates 1 0.515 2022.6 -2534.5  
## + fixed.acidity:total.sulfur.dioxide 1 0.515 2022.6 -2534.5  
## + residual.sugar:total.sulfur.dioxide 1 0.425 2022.7 -2534.4  
## + citric.acid:sulphates 1 0.371 2022.8 -2534.3  
## + volatile.acidity:chlorides 1 0.364 2022.8 -2534.2  
## + volatile.acidity:residual.sugar 1 0.284 2022.8 -2534.1  
## + total.sulfur.dioxide:density 1 0.273 2022.9 -2534.1  
## + chlorides:total.sulfur.dioxide 1 0.216 2022.9 -2534.0  
## + volatile.acidity:free.sulfur.dioxide 1 0.211 2022.9 -2533.9  
## + fixed.acidity:residual.sugar 1 0.163 2023.0 -2533.9  
## + residual.sugar:density 1 0.133 2023.0 -2533.8  
## + fixed.acidity:density 1 0.123 2023.0 -2533.8  
## + density:pH 1 0.121 2023.0 -2533.8  
## + chlorides:free.sulfur.dioxide 1 0.109 2023.0 -2533.8  
## + chlorides:alcohol 1 0.048 2023.1 -2533.6  
## + citric.acid:chlorides 1 0.047 2023.1 -2533.6  
## + total.sulfur.dioxide:alcohol 1 0.017 2023.1 -2533.6  
## + sulphates:alcohol 1 0.011 2023.1 -2533.6  
## + fixed.acidity:chlorides 1 0.008 2023.1 -2533.6  
## + citric.acid:free.sulfur.dioxide 1 0.001 2023.1 -2533.5  
## - fixed.acidity:free.sulfur.dioxide 1 2.892 2026.0 -2531.9  
## - free.sulfur.dioxide:density 1 3.666 2026.8 -2530.4  
## - citric.acid:pH 1 3.934 2027.1 -2529.9  
## - fixed.acidity:citric.acid 1 4.399 2027.5 -2529.0  
## - chlorides:density 1 5.787 2028.9 -2526.3  
## - residual.sugar:pH 1 6.133 2029.3 -2525.7  
## - pH:alcohol 1 6.761 2029.9 -2524.5  
## - chlorides:sulphates 1 6.993 2030.1 -2524.0  
## - density:alcohol 1 7.018 2030.2 -2524.0  
## - residual.sugar:free.sulfur.dioxide 1 7.625 2030.8 -2522.8  
## - residual.sugar:chlorides 1 9.374 2032.5 -2519.4  
## - free.sulfur.dioxide:alcohol 1 9.725 2032.9 -2518.8  
## - volatile.acidity:density 1 10.918 2034.0 -2516.4  
## - volatile.acidity:alcohol 1 32.650 2055.8 -2474.8  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 47.257 2070.4 -2447.1  
##   
## Step: AIC=-2540.93  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates  
##   
## Df Sum of Sq RSS AIC  
## + free.sulfur.dioxide:sulphates 1 6.590 2012.7 -2551.7  
## + chlorides:pH 1 3.136 2016.2 -2545.0  
## + fixed.acidity:volatile.acidity 1 2.249 2017.1 -2543.3  
## + fixed.acidity:pH 1 1.926 2017.4 -2542.7  
## + free.sulfur.dioxide:pH 1 1.900 2017.4 -2542.6  
## + citric.acid:residual.sugar 1 1.756 2017.6 -2542.3  
## + volatile.acidity:pH 1 1.710 2017.6 -2542.2  
## + total.sulfur.dioxide:pH 1 1.562 2017.8 -2542.0  
## + citric.acid:density 1 1.525 2017.8 -2541.9  
## + volatile.acidity:sulphates 1 1.406 2017.9 -2541.7  
## + pH:sulphates 1 1.295 2018.0 -2541.4  
## <none> 2019.3 -2540.9  
## + volatile.acidity:total.sulfur.dioxide 1 0.925 2018.4 -2540.7  
## + residual.sugar:alcohol 1 0.844 2018.5 -2540.6  
## + citric.acid:alcohol 1 0.793 2018.5 -2540.5  
## + sulphates:alcohol 1 0.766 2018.5 -2540.4  
## + residual.sugar:sulphates 1 0.699 2018.6 -2540.3  
## + citric.acid:total.sulfur.dioxide 1 0.651 2018.7 -2540.2  
## + volatile.acidity:citric.acid 1 0.597 2018.7 -2540.1  
## + total.sulfur.dioxide:density 1 0.589 2018.7 -2540.1  
## + fixed.acidity:alcohol 1 0.496 2018.8 -2539.9  
## + residual.sugar:total.sulfur.dioxide 1 0.478 2018.8 -2539.9  
## + fixed.acidity:total.sulfur.dioxide 1 0.409 2018.9 -2539.7  
## + volatile.acidity:residual.sugar 1 0.320 2019.0 -2539.6  
## + fixed.acidity:sulphates 1 0.303 2019.0 -2539.5  
## + residual.sugar:density 1 0.227 2019.1 -2539.4  
## + fixed.acidity:residual.sugar 1 0.225 2019.1 -2539.4  
## + chlorides:total.sulfur.dioxide 1 0.166 2019.2 -2539.2  
## + volatile.acidity:chlorides 1 0.144 2019.2 -2539.2  
## + citric.acid:chlorides 1 0.143 2019.2 -2539.2  
## + citric.acid:sulphates 1 0.136 2019.2 -2539.2  
## + density:pH 1 0.101 2019.2 -2539.1  
## + fixed.acidity:density 1 0.087 2019.2 -2539.1  
## + volatile.acidity:free.sulfur.dioxide 1 0.077 2019.2 -2539.1  
## + total.sulfur.dioxide:alcohol 1 0.064 2019.3 -2539.1  
## + chlorides:free.sulfur.dioxide 1 0.052 2019.3 -2539.0  
## + chlorides:alcohol 1 0.025 2019.3 -2539.0  
## + citric.acid:free.sulfur.dioxide 1 0.016 2019.3 -2539.0  
## + density:sulphates 1 0.015 2019.3 -2539.0  
## + fixed.acidity:chlorides 1 0.002 2019.3 -2538.9  
## - fixed.acidity:free.sulfur.dioxide 1 2.292 2021.6 -2538.5  
## - total.sulfur.dioxide:sulphates 1 3.812 2023.1 -2535.5  
## - citric.acid:pH 1 3.845 2023.2 -2535.5  
## - fixed.acidity:citric.acid 1 3.997 2023.3 -2535.2  
## - chlorides:sulphates 1 4.568 2023.9 -2534.1  
## - free.sulfur.dioxide:density 1 5.071 2024.4 -2533.1  
## - chlorides:density 1 6.064 2025.4 -2531.2  
## - residual.sugar:pH 1 6.214 2025.5 -2530.9  
## - pH:alcohol 1 6.404 2025.7 -2530.5  
## - density:alcohol 1 7.174 2026.5 -2529.0  
## - residual.sugar:free.sulfur.dioxide 1 9.366 2028.7 -2524.8  
## - residual.sugar:chlorides 1 9.870 2029.2 -2523.8  
## - free.sulfur.dioxide:alcohol 1 11.680 2031.0 -2520.3  
## - volatile.acidity:density 1 12.072 2031.4 -2519.6  
## - volatile.acidity:alcohol 1 33.475 2052.8 -2478.5  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 43.642 2063.0 -2459.2  
##   
## Step: AIC=-2551.74  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates  
##   
## Df Sum of Sq RSS AIC  
## + chlorides:pH 1 3.133 2009.6 -2555.8  
## + fixed.acidity:volatile.acidity 1 2.169 2010.6 -2554.0  
## + citric.acid:residual.sugar 1 1.780 2011.0 -2553.2  
## + fixed.acidity:pH 1 1.759 2011.0 -2553.2  
## + volatile.acidity:pH 1 1.756 2011.0 -2553.2  
## + volatile.acidity:total.sulfur.dioxide 1 1.718 2011.0 -2553.1  
## + free.sulfur.dioxide:pH 1 1.548 2011.2 -2552.8  
## + citric.acid:density 1 1.502 2011.2 -2552.7  
## <none> 2012.7 -2551.7  
## + residual.sugar:sulphates 1 1.007 2011.7 -2551.7  
## + total.sulfur.dioxide:pH 1 0.988 2011.7 -2551.7  
## + residual.sugar:alcohol 1 0.933 2011.8 -2551.6  
## + pH:sulphates 1 0.821 2011.9 -2551.3  
## + citric.acid:total.sulfur.dioxide 1 0.730 2012.0 -2551.2  
## + sulphates:alcohol 1 0.711 2012.0 -2551.1  
## + citric.acid:alcohol 1 0.694 2012.0 -2551.1  
## + volatile.acidity:citric.acid 1 0.649 2012.1 -2551.0  
## + fixed.acidity:alcohol 1 0.639 2012.1 -2551.0  
## + fixed.acidity:total.sulfur.dioxide 1 0.624 2012.1 -2550.9  
## + total.sulfur.dioxide:density 1 0.610 2012.1 -2550.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.497 2012.2 -2550.7  
## + residual.sugar:total.sulfur.dioxide 1 0.351 2012.4 -2550.4  
## + volatile.acidity:residual.sugar 1 0.270 2012.5 -2550.3  
## + volatile.acidity:sulphates 1 0.222 2012.5 -2550.2  
## + citric.acid:chlorides 1 0.181 2012.5 -2550.1  
## + fixed.acidity:residual.sugar 1 0.169 2012.6 -2550.1  
## + fixed.acidity:density 1 0.166 2012.6 -2550.1  
## + volatile.acidity:chlorides 1 0.140 2012.6 -2550.0  
## + citric.acid:sulphates 1 0.137 2012.6 -2550.0  
## + chlorides:total.sulfur.dioxide 1 0.118 2012.6 -2550.0  
## + density:pH 1 0.092 2012.6 -2549.9  
## + residual.sugar:density 1 0.065 2012.7 -2549.9  
## + total.sulfur.dioxide:alcohol 1 0.034 2012.7 -2549.8  
## + citric.acid:free.sulfur.dioxide 1 0.034 2012.7 -2549.8  
## + chlorides:free.sulfur.dioxide 1 0.026 2012.7 -2549.8  
## + fixed.acidity:sulphates 1 0.016 2012.7 -2549.8  
## + fixed.acidity:chlorides 1 0.006 2012.7 -2549.8  
## + density:sulphates 1 0.003 2012.7 -2549.7  
## + chlorides:alcohol 1 0.002 2012.7 -2549.7  
## - free.sulfur.dioxide:density 1 2.773 2015.5 -2548.3  
## - citric.acid:pH 1 3.222 2016.0 -2547.5  
## - fixed.acidity:free.sulfur.dioxide 1 3.599 2016.3 -2546.7  
## - fixed.acidity:citric.acid 1 3.602 2016.3 -2546.7  
## - chlorides:sulphates 1 4.064 2016.8 -2545.8  
## - residual.sugar:pH 1 5.806 2018.5 -2542.4  
## - pH:alcohol 1 6.062 2018.8 -2542.0  
## - residual.sugar:free.sulfur.dioxide 1 6.072 2018.8 -2541.9  
## - chlorides:density 1 6.558 2019.3 -2541.0  
## - free.sulfur.dioxide:sulphates 1 6.590 2019.3 -2540.9  
## - density:alcohol 1 6.912 2019.6 -2540.3  
## - free.sulfur.dioxide:alcohol 1 7.298 2020.0 -2539.6  
## - total.sulfur.dioxide:sulphates 1 9.386 2022.1 -2535.5  
## - residual.sugar:chlorides 1 10.209 2022.9 -2533.9  
## - volatile.acidity:density 1 10.465 2023.2 -2533.4  
## - volatile.acidity:alcohol 1 32.669 2045.4 -2490.7  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 47.706 2060.4 -2462.0  
##   
## Step: AIC=-2555.84  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH  
##   
## Df Sum of Sq RSS AIC  
## + volatile.acidity:pH 1 2.992 2006.6 -2559.7  
## + fixed.acidity:volatile.acidity 1 2.793 2006.8 -2559.3  
## + fixed.acidity:pH 1 1.869 2007.7 -2557.5  
## + volatile.acidity:total.sulfur.dioxide 1 1.660 2007.9 -2557.1  
## + citric.acid:residual.sugar 1 1.466 2008.1 -2556.7  
## + free.sulfur.dioxide:pH 1 1.417 2008.2 -2556.6  
## + citric.acid:density 1 1.285 2008.3 -2556.3  
## + pH:sulphates 1 1.276 2008.3 -2556.3  
## + residual.sugar:sulphates 1 1.086 2008.5 -2556.0  
## <none> 2009.6 -2555.8  
## + fixed.acidity:total.sulfur.dioxide 1 1.016 2008.6 -2555.8  
## + fixed.acidity:chlorides 1 0.945 2008.7 -2555.7  
## + residual.sugar:alcohol 1 0.795 2008.8 -2555.4  
## + citric.acid:total.sulfur.dioxide 1 0.721 2008.9 -2555.2  
## + citric.acid:alcohol 1 0.685 2008.9 -2555.2  
## + sulphates:alcohol 1 0.632 2009.0 -2555.1  
## + fixed.acidity:alcohol 1 0.607 2009.0 -2555.0  
## + total.sulfur.dioxide:density 1 0.561 2009.0 -2554.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.523 2009.1 -2554.9  
## + volatile.acidity:citric.acid 1 0.499 2009.1 -2554.8  
## + total.sulfur.dioxide:pH 1 0.461 2009.1 -2554.7  
## + volatile.acidity:residual.sugar 1 0.364 2009.2 -2554.6  
## + chlorides:alcohol 1 0.283 2009.3 -2554.4  
## + residual.sugar:total.sulfur.dioxide 1 0.262 2009.3 -2554.3  
## + fixed.acidity:density 1 0.236 2009.4 -2554.3  
## + volatile.acidity:sulphates 1 0.223 2009.4 -2554.3  
## + citric.acid:sulphates 1 0.166 2009.4 -2554.2  
## + fixed.acidity:residual.sugar 1 0.125 2009.5 -2554.1  
## + residual.sugar:density 1 0.115 2009.5 -2554.1  
## + fixed.acidity:sulphates 1 0.049 2009.5 -2553.9  
## + citric.acid:free.sulfur.dioxide 1 0.048 2009.5 -2553.9  
## + chlorides:total.sulfur.dioxide 1 0.043 2009.5 -2553.9  
## + total.sulfur.dioxide:alcohol 1 0.032 2009.6 -2553.9  
## + chlorides:free.sulfur.dioxide 1 0.015 2009.6 -2553.9  
## + citric.acid:chlorides 1 0.009 2009.6 -2553.9  
## + volatile.acidity:chlorides 1 0.007 2009.6 -2553.9  
## + density:sulphates 1 0.003 2009.6 -2553.8  
## + density:pH 1 0.003 2009.6 -2553.8  
## - pH:alcohol 1 2.626 2012.2 -2552.7  
## - free.sulfur.dioxide:density 1 2.839 2012.4 -2552.3  
## - chlorides:pH 1 3.133 2012.7 -2551.7  
## - fixed.acidity:free.sulfur.dioxide 1 3.335 2012.9 -2551.3  
## - citric.acid:pH 1 3.467 2013.1 -2551.1  
## - fixed.acidity:citric.acid 1 3.493 2013.1 -2551.0  
## - chlorides:sulphates 1 4.042 2013.6 -2550.0  
## - residual.sugar:free.sulfur.dioxide 1 6.033 2015.6 -2546.1  
## - chlorides:density 1 6.113 2015.7 -2545.9  
## - residual.sugar:pH 1 6.134 2015.7 -2545.9  
## - free.sulfur.dioxide:sulphates 1 6.587 2016.2 -2545.0  
## - density:alcohol 1 7.319 2016.9 -2543.6  
## - free.sulfur.dioxide:alcohol 1 7.523 2017.1 -2543.2  
## - total.sulfur.dioxide:sulphates 1 9.481 2019.1 -2539.4  
## - residual.sugar:chlorides 1 10.690 2020.3 -2537.1  
## - volatile.acidity:density 1 10.975 2020.6 -2536.5  
## - volatile.acidity:alcohol 1 33.237 2042.8 -2493.6  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 47.283 2056.9 -2466.7  
##   
## Step: AIC=-2559.68  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH  
##   
## Df Sum of Sq RSS AIC  
## + volatile.acidity:total.sulfur.dioxide 1 1.736 2004.9 -2561.1  
## + fixed.acidity:pH 1 1.699 2004.9 -2561.0  
## + free.sulfur.dioxide:pH 1 1.367 2005.2 -2560.3  
## + volatile.acidity:citric.acid 1 1.262 2005.3 -2560.1  
## + citric.acid:residual.sugar 1 1.209 2005.4 -2560.0  
## + pH:sulphates 1 1.158 2005.5 -2559.9  
## + total.sulfur.dioxide:pH 1 1.156 2005.5 -2559.9  
## + residual.sugar:alcohol 1 1.054 2005.5 -2559.7  
## <none> 2006.6 -2559.7  
## + residual.sugar:sulphates 1 0.998 2005.6 -2559.6  
## + fixed.acidity:volatile.acidity 1 0.943 2005.7 -2559.5  
## + citric.acid:density 1 0.891 2005.7 -2559.4  
## + fixed.acidity:chlorides 1 0.802 2005.8 -2559.2  
## + fixed.acidity:total.sulfur.dioxide 1 0.689 2005.9 -2559.0  
## - pH:alcohol 1 1.366 2008.0 -2559.0  
## + sulphates:alcohol 1 0.666 2005.9 -2559.0  
## + volatile.acidity:free.sulfur.dioxide 1 0.619 2006.0 -2558.9  
## + fixed.acidity:alcohol 1 0.530 2006.1 -2558.7  
## + citric.acid:total.sulfur.dioxide 1 0.470 2006.1 -2558.6  
## + total.sulfur.dioxide:density 1 0.433 2006.2 -2558.5  
## + volatile.acidity:sulphates 1 0.369 2006.2 -2558.4  
## + citric.acid:alcohol 1 0.358 2006.2 -2558.4  
## + chlorides:alcohol 1 0.268 2006.3 -2558.2  
## + residual.sugar:total.sulfur.dioxide 1 0.211 2006.4 -2558.1  
## + fixed.acidity:density 1 0.173 2006.4 -2558.0  
## + fixed.acidity:residual.sugar 1 0.120 2006.5 -2557.9  
## + volatile.acidity:residual.sugar 1 0.116 2006.5 -2557.9  
## + citric.acid:sulphates 1 0.088 2006.5 -2557.8  
## + volatile.acidity:chlorides 1 0.047 2006.6 -2557.8  
## + chlorides:total.sulfur.dioxide 1 0.047 2006.6 -2557.8  
## + residual.sugar:density 1 0.032 2006.6 -2557.7  
## + citric.acid:free.sulfur.dioxide 1 0.025 2006.6 -2557.7  
## + total.sulfur.dioxide:alcohol 1 0.022 2006.6 -2557.7  
## + fixed.acidity:sulphates 1 0.015 2006.6 -2557.7  
## + chlorides:free.sulfur.dioxide 1 0.012 2006.6 -2557.7  
## + density:pH 1 0.006 2006.6 -2557.7  
## + citric.acid:chlorides 1 0.002 2006.6 -2557.7  
## + density:sulphates 1 0.000 2006.6 -2557.7  
## - fixed.acidity:free.sulfur.dioxide 1 2.597 2009.2 -2556.6  
## - volatile.acidity:pH 1 2.992 2009.6 -2555.8  
## - free.sulfur.dioxide:density 1 3.591 2010.2 -2554.7  
## - chlorides:sulphates 1 3.663 2010.3 -2554.5  
## - fixed.acidity:citric.acid 1 3.783 2010.4 -2554.3  
## - chlorides:pH 1 4.369 2011.0 -2553.2  
## - citric.acid:pH 1 4.516 2011.1 -2552.9  
## - chlorides:density 1 6.048 2012.7 -2549.9  
## - free.sulfur.dioxide:sulphates 1 6.647 2013.2 -2548.7  
## - residual.sugar:free.sulfur.dioxide 1 6.918 2013.5 -2548.2  
## - density:alcohol 1 7.430 2014.0 -2547.2  
## - residual.sugar:pH 1 7.568 2014.2 -2546.9  
## - free.sulfur.dioxide:alcohol 1 8.315 2014.9 -2545.5  
## - total.sulfur.dioxide:sulphates 1 9.553 2016.2 -2543.1  
## - residual.sugar:chlorides 1 10.652 2017.3 -2540.9  
## - volatile.acidity:density 1 11.638 2018.2 -2539.0  
## - volatile.acidity:alcohol 1 31.050 2037.7 -2501.5  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 48.693 2055.3 -2467.7  
##   
## Step: AIC=-2561.07  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide  
##   
## Df Sum of Sq RSS AIC  
## + fixed.acidity:pH 1 1.713 2003.2 -2562.4  
## + fixed.acidity:volatile.acidity 1 1.323 2003.5 -2561.7  
## + pH:sulphates 1 1.160 2003.7 -2561.3  
## + citric.acid:residual.sugar 1 1.042 2003.8 -2561.1  
## <none> 2004.9 -2561.1  
## + total.sulfur.dioxide:pH 1 1.000 2003.9 -2561.0  
## + free.sulfur.dioxide:pH 1 1.000 2003.9 -2561.0  
## + residual.sugar:alcohol 1 0.989 2003.9 -2561.0  
## + residual.sugar:sulphates 1 0.923 2004.0 -2560.9  
## + volatile.acidity:sulphates 1 0.913 2004.0 -2560.8  
## + fixed.acidity:chlorides 1 0.811 2004.1 -2560.7  
## + volatile.acidity:citric.acid 1 0.786 2004.1 -2560.6  
## + citric.acid:density 1 0.759 2004.1 -2560.6  
## + sulphates:alcohol 1 0.686 2004.2 -2560.4  
## - pH:alcohol 1 1.398 2006.3 -2560.3  
## + fixed.acidity:total.sulfur.dioxide 1 0.573 2004.3 -2560.2  
## + fixed.acidity:alcohol 1 0.519 2004.3 -2560.1  
## + total.sulfur.dioxide:density 1 0.485 2004.4 -2560.0  
## + citric.acid:alcohol 1 0.399 2004.5 -2559.8  
## - volatile.acidity:total.sulfur.dioxide 1 1.736 2006.6 -2559.7  
## + chlorides:alcohol 1 0.285 2004.6 -2559.6  
## + residual.sugar:density 1 0.273 2004.6 -2559.6  
## + citric.acid:total.sulfur.dioxide 1 0.246 2004.6 -2559.6  
## + residual.sugar:total.sulfur.dioxide 1 0.237 2004.6 -2559.5  
## + fixed.acidity:residual.sugar 1 0.217 2004.7 -2559.5  
## + fixed.acidity:density 1 0.131 2004.7 -2559.3  
## + chlorides:total.sulfur.dioxide 1 0.128 2004.7 -2559.3  
## + volatile.acidity:residual.sugar 1 0.089 2004.8 -2559.2  
## + total.sulfur.dioxide:alcohol 1 0.033 2004.8 -2559.1  
## + citric.acid:sulphates 1 0.029 2004.8 -2559.1  
## + chlorides:free.sulfur.dioxide 1 0.004 2004.9 -2559.1  
## + fixed.acidity:sulphates 1 0.003 2004.9 -2559.1  
## + volatile.acidity:free.sulfur.dioxide 1 0.003 2004.9 -2559.1  
## + density:sulphates 1 0.002 2004.9 -2559.1  
## + citric.acid:chlorides 1 0.002 2004.9 -2559.1  
## + volatile.acidity:chlorides 1 0.001 2004.9 -2559.1  
## + citric.acid:free.sulfur.dioxide 1 0.001 2004.9 -2559.1  
## + density:pH 1 0.000 2004.9 -2559.1  
## - free.sulfur.dioxide:density 1 2.736 2007.6 -2557.7  
## - volatile.acidity:pH 1 3.067 2007.9 -2557.1  
## - fixed.acidity:free.sulfur.dioxide 1 3.170 2008.0 -2556.9  
## - fixed.acidity:citric.acid 1 3.737 2008.6 -2555.8  
## - chlorides:sulphates 1 3.972 2008.8 -2555.3  
## - chlorides:pH 1 4.320 2009.2 -2554.6  
## - citric.acid:pH 1 4.735 2009.6 -2553.8  
## - chlorides:density 1 5.995 2010.9 -2551.4  
## - residual.sugar:free.sulfur.dioxide 1 6.030 2010.9 -2551.3  
## - free.sulfur.dioxide:alcohol 1 6.889 2011.8 -2549.6  
## - density:alcohol 1 7.087 2012.0 -2549.2  
## - residual.sugar:pH 1 7.256 2012.1 -2548.9  
## - free.sulfur.dioxide:sulphates 1 7.449 2012.3 -2548.5  
## - volatile.acidity:density 1 8.087 2013.0 -2547.3  
## - total.sulfur.dioxide:sulphates 1 9.622 2014.5 -2544.3  
## - residual.sugar:chlorides 1 10.557 2015.4 -2542.5  
## - volatile.acidity:alcohol 1 32.761 2037.6 -2499.6  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 48.302 2053.2 -2469.8  
##   
## Step: AIC=-2562.42  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH  
##   
## Df Sum of Sq RSS AIC  
## + pH:sulphates 1 1.483 2001.7 -2563.3  
## + fixed.acidity:volatile.acidity 1 1.150 2002.0 -2562.7  
## + citric.acid:residual.sugar 1 1.138 2002.0 -2562.6  
## <none> 2003.2 -2562.4  
## + residual.sugar:sulphates 1 1.007 2002.2 -2562.4  
## + residual.sugar:alcohol 1 0.997 2002.2 -2562.4  
## + free.sulfur.dioxide:pH 1 0.914 2002.2 -2562.2  
## + fixed.acidity:chlorides 1 0.894 2002.3 -2562.2  
## + volatile.acidity:sulphates 1 0.871 2002.3 -2562.1  
## + total.sulfur.dioxide:pH 1 0.866 2002.3 -2562.1  
## + citric.acid:density 1 0.848 2002.3 -2562.1  
## + volatile.acidity:citric.acid 1 0.763 2002.4 -2561.9  
## + fixed.acidity:total.sulfur.dioxide 1 0.664 2002.5 -2561.7  
## + sulphates:alcohol 1 0.616 2002.5 -2561.6  
## + total.sulfur.dioxide:density 1 0.589 2002.6 -2561.6  
## + citric.acid:alcohol 1 0.412 2002.7 -2561.2  
## + fixed.acidity:alcohol 1 0.397 2002.8 -2561.2  
## + fixed.acidity:residual.sugar 1 0.378 2002.8 -2561.2  
## - fixed.acidity:pH 1 1.713 2004.9 -2561.1  
## + residual.sugar:total.sulfur.dioxide 1 0.323 2002.8 -2561.1  
## + residual.sugar:density 1 0.307 2002.8 -2561.0  
## - volatile.acidity:total.sulfur.dioxide 1 1.750 2004.9 -2561.0  
## + chlorides:alcohol 1 0.270 2002.9 -2560.9  
## + citric.acid:total.sulfur.dioxide 1 0.235 2002.9 -2560.9  
## + volatile.acidity:residual.sugar 1 0.156 2003.0 -2560.7  
## - pH:alcohol 1 1.916 2005.1 -2560.7  
## + density:pH 1 0.129 2003.0 -2560.7  
## + chlorides:total.sulfur.dioxide 1 0.105 2003.0 -2560.6  
## + fixed.acidity:density 1 0.056 2003.1 -2560.5  
## + fixed.acidity:sulphates 1 0.044 2003.1 -2560.5  
## + total.sulfur.dioxide:alcohol 1 0.040 2003.1 -2560.5  
## + citric.acid:sulphates 1 0.019 2003.1 -2560.5  
## + citric.acid:chlorides 1 0.006 2003.2 -2560.4  
## + chlorides:free.sulfur.dioxide 1 0.005 2003.2 -2560.4  
## + volatile.acidity:chlorides 1 0.004 2003.2 -2560.4  
## + density:sulphates 1 0.000 2003.2 -2560.4  
## + citric.acid:free.sulfur.dioxide 1 0.000 2003.2 -2560.4  
## + volatile.acidity:free.sulfur.dioxide 1 0.000 2003.2 -2560.4  
## - fixed.acidity:free.sulfur.dioxide 1 2.495 2005.7 -2559.5  
## - fixed.acidity:citric.acid 1 2.827 2006.0 -2558.9  
## - volatile.acidity:pH 1 2.895 2006.0 -2558.8  
## - free.sulfur.dioxide:density 1 3.004 2006.2 -2558.6  
## - citric.acid:pH 1 3.250 2006.4 -2558.1  
## - chlorides:sulphates 1 3.934 2007.1 -2556.7  
## - chlorides:pH 1 4.399 2007.5 -2555.8  
## - chlorides:density 1 6.292 2009.5 -2552.1  
## - residual.sugar:free.sulfur.dioxide 1 6.322 2009.5 -2552.1  
## - density:alcohol 1 6.747 2009.9 -2551.2  
## - residual.sugar:pH 1 7.236 2010.4 -2550.3  
## - free.sulfur.dioxide:sulphates 1 7.277 2010.4 -2550.2  
## - free.sulfur.dioxide:alcohol 1 7.315 2010.5 -2550.1  
## - volatile.acidity:density 1 8.344 2011.5 -2548.1  
## - total.sulfur.dioxide:sulphates 1 9.234 2012.4 -2546.4  
## - residual.sugar:chlorides 1 10.722 2013.9 -2543.5  
## - volatile.acidity:alcohol 1 33.285 2036.4 -2499.8  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 48.022 2051.2 -2471.6  
##   
## Step: AIC=-2563.32  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates  
##   
## Df Sum of Sq RSS AIC  
## + total.sulfur.dioxide:pH 1 1.297 2000.4 -2563.9  
## + citric.acid:residual.sugar 1 1.118 2000.6 -2563.5  
## + fixed.acidity:volatile.acidity 1 1.042 2000.6 -2563.4  
## <none> 2001.7 -2563.3  
## + free.sulfur.dioxide:pH 1 0.981 2000.7 -2563.2  
## + residual.sugar:alcohol 1 0.968 2000.7 -2563.2  
## + volatile.acidity:citric.acid 1 0.882 2000.8 -2563.1  
## + citric.acid:density 1 0.860 2000.8 -2563.0  
## + fixed.acidity:chlorides 1 0.813 2000.9 -2562.9  
## + density:pH 1 0.802 2000.9 -2562.9  
## + sulphates:alcohol 1 0.769 2000.9 -2562.8  
## + volatile.acidity:sulphates 1 0.755 2000.9 -2562.8  
## + residual.sugar:sulphates 1 0.688 2001.0 -2562.7  
## + total.sulfur.dioxide:density 1 0.636 2001.0 -2562.6  
## - pH:sulphates 1 1.483 2003.2 -2562.4  
## + citric.acid:alcohol 1 0.497 2001.2 -2562.3  
## + fixed.acidity:residual.sugar 1 0.439 2001.2 -2562.2  
## + fixed.acidity:total.sulfur.dioxide 1 0.410 2001.3 -2562.1  
## + residual.sugar:total.sulfur.dioxide 1 0.360 2001.3 -2562.0  
## + fixed.acidity:alcohol 1 0.335 2001.3 -2562.0  
## + chlorides:alcohol 1 0.302 2001.4 -2561.9  
## + residual.sugar:density 1 0.297 2001.4 -2561.9  
## - pH:alcohol 1 1.752 2003.4 -2561.9  
## - volatile.acidity:total.sulfur.dioxide 1 1.754 2003.4 -2561.9  
## + citric.acid:total.sulfur.dioxide 1 0.181 2001.5 -2561.7  
## + volatile.acidity:residual.sugar 1 0.159 2001.5 -2561.6  
## + fixed.acidity:sulphates 1 0.116 2001.6 -2561.6  
## + chlorides:total.sulfur.dioxide 1 0.080 2001.6 -2561.5  
## + total.sulfur.dioxide:alcohol 1 0.044 2001.6 -2561.4  
## + citric.acid:sulphates 1 0.021 2001.7 -2561.4  
## + citric.acid:chlorides 1 0.017 2001.7 -2561.3  
## + fixed.acidity:density 1 0.011 2001.7 -2561.3  
## + chlorides:free.sulfur.dioxide 1 0.009 2001.7 -2561.3  
## - fixed.acidity:pH 1 2.036 2003.7 -2561.3  
## + citric.acid:free.sulfur.dioxide 1 0.003 2001.7 -2561.3  
## + volatile.acidity:chlorides 1 0.003 2001.7 -2561.3  
## + volatile.acidity:free.sulfur.dioxide 1 0.001 2001.7 -2561.3  
## + density:sulphates 1 0.000 2001.7 -2561.3  
## - fixed.acidity:citric.acid 1 2.520 2004.2 -2560.4  
## - fixed.acidity:free.sulfur.dioxide 1 2.628 2004.3 -2560.2  
## - volatile.acidity:pH 1 2.747 2004.4 -2559.9  
## - free.sulfur.dioxide:density 1 2.767 2004.4 -2559.9  
## - citric.acid:pH 1 3.015 2004.7 -2559.4  
## - chlorides:sulphates 1 3.778 2005.5 -2557.9  
## - chlorides:pH 1 4.941 2006.6 -2555.7  
## - residual.sugar:free.sulfur.dioxide 1 5.853 2007.5 -2553.9  
## - chlorides:density 1 6.097 2007.8 -2553.4  
## - free.sulfur.dioxide:sulphates 1 6.607 2008.3 -2552.4  
## - residual.sugar:pH 1 6.718 2008.4 -2552.2  
## - density:alcohol 1 7.029 2008.7 -2551.6  
## - free.sulfur.dioxide:alcohol 1 7.158 2008.8 -2551.3  
## - volatile.acidity:density 1 8.356 2010.0 -2549.0  
## - total.sulfur.dioxide:sulphates 1 9.212 2010.9 -2547.3  
## - residual.sugar:chlorides 1 10.428 2012.1 -2545.0  
## - volatile.acidity:alcohol 1 32.309 2034.0 -2502.6  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 46.848 2048.5 -2474.7  
##   
## Step: AIC=-2563.86  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH  
##   
## Df Sum of Sq RSS AIC  
## + fixed.acidity:total.sulfur.dioxide 1 1.290 1999.1 -2564.4  
## + citric.acid:residual.sugar 1 1.115 1999.3 -2564.0  
## - fixed.acidity:free.sulfur.dioxide 1 0.959 2001.3 -2564.0  
## + fixed.acidity:volatile.acidity 1 1.038 1999.3 -2563.9  
## <none> 2000.4 -2563.9  
## + residual.sugar:alcohol 1 1.012 1999.4 -2563.8  
## - pH:alcohol 1 1.110 2001.5 -2563.7  
## + volatile.acidity:citric.acid 1 0.873 1999.5 -2563.6  
## + citric.acid:density 1 0.854 1999.5 -2563.5  
## + volatile.acidity:sulphates 1 0.776 1999.6 -2563.4  
## + fixed.acidity:chlorides 1 0.769 1999.6 -2563.4  
## - total.sulfur.dioxide:pH 1 1.297 2001.7 -2563.3  
## + sulphates:alcohol 1 0.727 1999.7 -2563.3  
## + residual.sugar:sulphates 1 0.715 1999.7 -2563.3  
## - volatile.acidity:total.sulfur.dioxide 1 1.575 2002.0 -2562.8  
## + citric.acid:total.sulfur.dioxide 1 0.448 1999.9 -2562.7  
## + total.sulfur.dioxide:density 1 0.441 1999.9 -2562.7  
## + citric.acid:alcohol 1 0.439 1999.9 -2562.7  
## + free.sulfur.dioxide:pH 1 0.395 2000.0 -2562.6  
## + fixed.acidity:residual.sugar 1 0.384 2000.0 -2562.6  
## + density:pH 1 0.304 2000.1 -2562.4  
## + chlorides:alcohol 1 0.298 2000.1 -2562.4  
## + residual.sugar:density 1 0.272 2000.1 -2562.4  
## + fixed.acidity:alcohol 1 0.272 2000.1 -2562.4  
## + volatile.acidity:residual.sugar 1 0.179 2000.2 -2562.2  
## + chlorides:total.sulfur.dioxide 1 0.150 2000.2 -2562.2  
## - fixed.acidity:pH 1 1.911 2002.3 -2562.1  
## - pH:sulphates 1 1.914 2002.3 -2562.1  
## + residual.sugar:total.sulfur.dioxide 1 0.128 2000.2 -2562.1  
## + fixed.acidity:sulphates 1 0.077 2000.3 -2562.0  
## + fixed.acidity:density 1 0.027 2000.3 -2561.9  
## + citric.acid:free.sulfur.dioxide 1 0.013 2000.4 -2561.9  
## + volatile.acidity:chlorides 1 0.010 2000.4 -2561.9  
## + citric.acid:sulphates 1 0.008 2000.4 -2561.9  
## + citric.acid:chlorides 1 0.005 2000.4 -2561.9  
## + total.sulfur.dioxide:alcohol 1 0.005 2000.4 -2561.9  
## + volatile.acidity:free.sulfur.dioxide 1 0.001 2000.4 -2561.9  
## + density:sulphates 1 0.000 2000.4 -2561.9  
## + chlorides:free.sulfur.dioxide 1 0.000 2000.4 -2561.9  
## - fixed.acidity:citric.acid 1 2.696 2003.1 -2560.6  
## - citric.acid:pH 1 3.219 2003.6 -2559.6  
## - volatile.acidity:pH 1 3.467 2003.8 -2559.1  
## - chlorides:sulphates 1 3.736 2004.1 -2558.6  
## - free.sulfur.dioxide:density 1 3.855 2004.2 -2558.3  
## - chlorides:pH 1 4.259 2004.6 -2557.5  
## - residual.sugar:pH 1 5.021 2005.4 -2556.0  
## - free.sulfur.dioxide:sulphates 1 5.791 2006.2 -2554.5  
## - chlorides:density 1 5.962 2006.3 -2554.2  
## - density:alcohol 1 6.920 2007.3 -2552.3  
## - residual.sugar:free.sulfur.dioxide 1 7.127 2007.5 -2551.9  
## - total.sulfur.dioxide:sulphates 1 8.340 2008.7 -2549.6  
## - free.sulfur.dioxide:alcohol 1 8.416 2008.8 -2549.4  
## - volatile.acidity:density 1 8.919 2009.3 -2548.4  
## - residual.sugar:chlorides 1 10.466 2010.8 -2545.4  
## - volatile.acidity:alcohol 1 32.654 2033.0 -2502.4  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.782 2046.2 -2477.2  
##   
## Step: AIC=-2564.39  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH +   
## fixed.acidity:total.sulfur.dioxide  
##   
## Df Sum of Sq RSS AIC  
## + residual.sugar:alcohol 1 1.167 1997.9 -2564.7  
## + citric.acid:residual.sugar 1 1.043 1998.0 -2564.4  
## - pH:alcohol 1 1.011 2000.1 -2564.4  
## <none> 1999.1 -2564.4  
## + total.sulfur.dioxide:density 1 0.934 1998.2 -2564.2  
## + volatile.acidity:citric.acid 1 0.908 1998.2 -2564.2  
## + volatile.acidity:sulphates 1 0.903 1998.2 -2564.2  
## + residual.sugar:sulphates 1 0.778 1998.3 -2563.9  
## + fixed.acidity:residual.sugar 1 0.756 1998.3 -2563.9  
## - fixed.acidity:total.sulfur.dioxide 1 1.290 2000.4 -2563.9  
## + citric.acid:density 1 0.744 1998.3 -2563.8  
## - volatile.acidity:total.sulfur.dioxide 1 1.334 2000.4 -2563.8  
## + sulphates:alcohol 1 0.694 1998.4 -2563.8  
## + fixed.acidity:volatile.acidity 1 0.637 1998.5 -2563.6  
## + fixed.acidity:chlorides 1 0.453 1998.6 -2563.3  
## - pH:sulphates 1 1.603 2000.7 -2563.2  
## + chlorides:alcohol 1 0.427 1998.7 -2563.2  
## + density:pH 1 0.374 1998.7 -2563.1  
## + volatile.acidity:residual.sugar 1 0.361 1998.7 -2563.1  
## + citric.acid:alcohol 1 0.346 1998.7 -2563.1  
## + citric.acid:total.sulfur.dioxide 1 0.287 1998.8 -2562.9  
## + residual.sugar:density 1 0.241 1998.8 -2562.9  
## + chlorides:total.sulfur.dioxide 1 0.174 1998.9 -2562.7  
## - fixed.acidity:free.sulfur.dioxide 1 1.870 2001.0 -2562.7  
## + fixed.acidity:sulphates 1 0.165 1998.9 -2562.7  
## + free.sulfur.dioxide:pH 1 0.162 1998.9 -2562.7  
## + residual.sugar:total.sulfur.dioxide 1 0.120 1999.0 -2562.6  
## + fixed.acidity:density 1 0.116 1999.0 -2562.6  
## - fixed.acidity:pH 1 1.959 2001.0 -2562.6  
## + citric.acid:sulphates 1 0.032 1999.0 -2562.4  
## + citric.acid:free.sulfur.dioxide 1 0.028 1999.1 -2562.4  
## + fixed.acidity:alcohol 1 0.020 1999.1 -2562.4  
## + total.sulfur.dioxide:alcohol 1 0.019 1999.1 -2562.4  
## + volatile.acidity:chlorides 1 0.006 1999.1 -2562.4  
## - fixed.acidity:citric.acid 1 2.041 2001.1 -2562.4  
## + density:sulphates 1 0.001 1999.1 -2562.4  
## + chlorides:free.sulfur.dioxide 1 0.001 1999.1 -2562.4  
## + citric.acid:chlorides 1 0.000 1999.1 -2562.4  
## + volatile.acidity:free.sulfur.dioxide 1 0.000 1999.1 -2562.4  
## - total.sulfur.dioxide:pH 1 2.177 2001.3 -2562.1  
## - volatile.acidity:pH 1 3.356 2002.4 -2559.8  
## - citric.acid:pH 1 3.507 2002.6 -2559.5  
## - chlorides:sulphates 1 3.920 2003.0 -2558.7  
## - free.sulfur.dioxide:density 1 4.321 2003.4 -2557.9  
## - chlorides:pH 1 4.427 2003.5 -2557.7  
## - residual.sugar:pH 1 5.154 2004.2 -2556.3  
## - free.sulfur.dioxide:sulphates 1 5.892 2005.0 -2554.9  
## - chlorides:density 1 6.283 2005.4 -2554.1  
## - density:alcohol 1 7.475 2006.6 -2551.8  
## - residual.sugar:free.sulfur.dioxide 1 7.747 2006.8 -2551.2  
## - total.sulfur.dioxide:sulphates 1 8.021 2007.1 -2550.7  
## - free.sulfur.dioxide:alcohol 1 9.162 2008.2 -2548.5  
## - volatile.acidity:density 1 9.440 2008.5 -2547.9  
## - residual.sugar:chlorides 1 10.946 2010.0 -2545.0  
## - volatile.acidity:alcohol 1 33.111 2032.2 -2502.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.639 2044.7 -2477.9  
##   
## Step: AIC=-2564.67  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH +   
## fixed.acidity:total.sulfur.dioxide + residual.sugar:alcohol  
##   
## Df Sum of Sq RSS AIC  
## + citric.acid:residual.sugar 1 1.268 1996.7 -2565.2  
## <none> 1997.9 -2564.7  
## + total.sulfur.dioxide:density 1 1.003 1996.9 -2564.6  
## + citric.acid:density 1 0.920 1997.0 -2564.5  
## + volatile.acidity:sulphates 1 0.874 1997.0 -2564.4  
## - residual.sugar:alcohol 1 1.167 1999.1 -2564.4  
## + volatile.acidity:citric.acid 1 0.835 1997.1 -2564.3  
## - pH:alcohol 1 1.214 1999.1 -2564.3  
## - volatile.acidity:total.sulfur.dioxide 1 1.257 1999.2 -2564.2  
## + residual.sugar:density 1 0.753 1997.2 -2564.2  
## + residual.sugar:sulphates 1 0.741 1997.2 -2564.1  
## + fixed.acidity:residual.sugar 1 0.651 1997.3 -2563.9  
## - fixed.acidity:total.sulfur.dioxide 1 1.445 1999.4 -2563.8  
## + sulphates:alcohol 1 0.555 1997.4 -2563.8  
## + fixed.acidity:volatile.acidity 1 0.542 1997.4 -2563.7  
## + volatile.acidity:residual.sugar 1 0.523 1997.4 -2563.7  
## - pH:sulphates 1 1.562 1999.5 -2563.6  
## + fixed.acidity:chlorides 1 0.476 1997.4 -2563.6  
## + chlorides:alcohol 1 0.443 1997.5 -2563.5  
## + citric.acid:alcohol 1 0.403 1997.5 -2563.5  
## + citric.acid:total.sulfur.dioxide 1 0.354 1997.6 -2563.4  
## + density:pH 1 0.314 1997.6 -2563.3  
## + fixed.acidity:alcohol 1 0.308 1997.6 -2563.3  
## + residual.sugar:total.sulfur.dioxide 1 0.287 1997.6 -2563.2  
## + chlorides:total.sulfur.dioxide 1 0.159 1997.8 -2563.0  
## + fixed.acidity:sulphates 1 0.152 1997.8 -2563.0  
## - fixed.acidity:free.sulfur.dioxide 1 1.901 1999.8 -2562.9  
## + free.sulfur.dioxide:pH 1 0.097 1997.8 -2562.9  
## - fixed.acidity:pH 1 1.965 1999.9 -2562.8  
## + citric.acid:free.sulfur.dioxide 1 0.071 1997.8 -2562.8  
## + citric.acid:sulphates 1 0.039 1997.9 -2562.8  
## + citric.acid:chlorides 1 0.008 1997.9 -2562.7  
## + fixed.acidity:density 1 0.007 1997.9 -2562.7  
## + density:sulphates 1 0.004 1997.9 -2562.7  
## + volatile.acidity:chlorides 1 0.003 1997.9 -2562.7  
## + volatile.acidity:free.sulfur.dioxide 1 0.000 1997.9 -2562.7  
## + chlorides:free.sulfur.dioxide 1 0.000 1997.9 -2562.7  
## + total.sulfur.dioxide:alcohol 1 0.000 1997.9 -2562.7  
## - fixed.acidity:citric.acid 1 2.103 2000.0 -2562.6  
## - total.sulfur.dioxide:pH 1 2.307 2000.2 -2562.2  
## - citric.acid:pH 1 3.620 2001.5 -2559.6  
## - volatile.acidity:pH 1 3.647 2001.6 -2559.5  
## - chlorides:sulphates 1 3.780 2001.7 -2559.3  
## - free.sulfur.dioxide:density 1 4.202 2002.1 -2558.4  
## - chlorides:pH 1 4.303 2002.2 -2558.2  
## - chlorides:density 1 4.578 2002.5 -2557.7  
## - residual.sugar:pH 1 5.502 2003.4 -2555.9  
## - free.sulfur.dioxide:sulphates 1 5.971 2003.9 -2555.0  
## - density:alcohol 1 6.193 2004.1 -2554.6  
## - residual.sugar:free.sulfur.dioxide 1 7.438 2005.4 -2552.1  
## - residual.sugar:chlorides 1 7.889 2005.8 -2551.2  
## - total.sulfur.dioxide:sulphates 1 8.038 2006.0 -2550.9  
## - free.sulfur.dioxide:alcohol 1 8.919 2006.8 -2549.2  
## - volatile.acidity:density 1 9.713 2007.6 -2547.7  
## - volatile.acidity:alcohol 1 31.200 2029.1 -2506.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.482 2043.4 -2478.5  
##   
## Step: AIC=-2565.16  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH +   
## fixed.acidity:total.sulfur.dioxide + residual.sugar:alcohol +   
## citric.acid:residual.sugar  
##   
## Df Sum of Sq RSS AIC  
## + fixed.acidity:residual.sugar 1 1.303 1995.3 -2565.7  
## + residual.sugar:density 1 1.289 1995.4 -2565.7  
## + total.sulfur.dioxide:density 1 1.139 1995.5 -2565.4  
## + volatile.acidity:citric.acid 1 1.115 1995.5 -2565.3  
## <none> 1996.7 -2565.2  
## - volatile.acidity:total.sulfur.dioxide 1 1.102 1997.8 -2565.0  
## + volatile.acidity:sulphates 1 0.923 1995.7 -2565.0  
## - citric.acid:residual.sugar 1 1.268 1997.9 -2564.7  
## - pH:alcohol 1 1.333 1998.0 -2564.6  
## + volatile.acidity:residual.sugar 1 0.664 1996.0 -2564.5  
## - fixed.acidity:total.sulfur.dioxide 1 1.377 1998.0 -2564.5  
## - residual.sugar:alcohol 1 1.392 1998.0 -2564.4  
## + fixed.acidity:volatile.acidity 1 0.591 1996.1 -2564.3  
## + residual.sugar:sulphates 1 0.577 1996.1 -2564.3  
## + sulphates:alcohol 1 0.563 1996.1 -2564.3  
## + chlorides:alcohol 1 0.542 1996.1 -2564.2  
## + fixed.acidity:chlorides 1 0.540 1996.1 -2564.2  
## - pH:sulphates 1 1.545 1998.2 -2564.1  
## + residual.sugar:total.sulfur.dioxide 1 0.388 1996.3 -2563.9  
## - fixed.acidity:citric.acid 1 1.733 1998.4 -2563.8  
## + fixed.acidity:alcohol 1 0.264 1996.4 -2563.7  
## + density:pH 1 0.228 1996.4 -2563.6  
## + fixed.acidity:sulphates 1 0.178 1996.5 -2563.5  
## + citric.acid:alcohol 1 0.120 1996.5 -2563.4  
## + chlorides:total.sulfur.dioxide 1 0.113 1996.5 -2563.4  
## + citric.acid:sulphates 1 0.100 1996.5 -2563.4  
## + fixed.acidity:density 1 0.064 1996.6 -2563.3  
## + free.sulfur.dioxide:pH 1 0.053 1996.6 -2563.3  
## + citric.acid:total.sulfur.dioxide 1 0.029 1996.6 -2563.2  
## - fixed.acidity:free.sulfur.dioxide 1 2.023 1998.7 -2563.2  
## + citric.acid:chlorides 1 0.009 1996.6 -2563.2  
## + volatile.acidity:chlorides 1 0.005 1996.7 -2563.2  
## + density:sulphates 1 0.001 1996.7 -2563.2  
## + total.sulfur.dioxide:alcohol 1 0.000 1996.7 -2563.2  
## + volatile.acidity:free.sulfur.dioxide 1 0.000 1996.7 -2563.2  
## + chlorides:free.sulfur.dioxide 1 0.000 1996.7 -2563.2  
## + citric.acid:density 1 0.000 1996.7 -2563.2  
## + citric.acid:free.sulfur.dioxide 1 0.000 1996.7 -2563.2  
## - fixed.acidity:pH 1 2.069 1998.7 -2563.1  
## - total.sulfur.dioxide:pH 1 2.276 1998.9 -2562.7  
## - citric.acid:pH 1 3.165 1999.8 -2561.0  
## - volatile.acidity:pH 1 3.387 2000.0 -2560.5  
## - chlorides:sulphates 1 3.541 2000.2 -2560.2  
## - chlorides:pH 1 3.880 2000.5 -2559.6  
## - free.sulfur.dioxide:density 1 4.233 2000.9 -2558.9  
## - chlorides:density 1 4.464 2001.1 -2558.4  
## - free.sulfur.dioxide:sulphates 1 5.948 2002.6 -2555.5  
## - residual.sugar:pH 1 5.956 2002.6 -2555.5  
## - density:alcohol 1 6.563 2003.2 -2554.3  
## - residual.sugar:free.sulfur.dioxide 1 7.338 2004.0 -2552.8  
## - residual.sugar:chlorides 1 7.354 2004.0 -2552.8  
## - total.sulfur.dioxide:sulphates 1 7.819 2004.5 -2551.8  
## - free.sulfur.dioxide:alcohol 1 9.022 2005.7 -2549.5  
## - volatile.acidity:density 1 10.781 2007.4 -2546.1  
## - volatile.acidity:alcohol 1 32.236 2028.9 -2504.4  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.231 2041.9 -2479.4  
##   
## Step: AIC=-2565.72  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH +   
## fixed.acidity:total.sulfur.dioxide + residual.sugar:alcohol +   
## citric.acid:residual.sugar + fixed.acidity:residual.sugar  
##   
## Df Sum of Sq RSS AIC  
## + volatile.acidity:citric.acid 1 1.163 1994.2 -2566.0  
## <none> 1995.3 -2565.7  
## + total.sulfur.dioxide:density 1 0.872 1994.5 -2565.4  
## + volatile.acidity:sulphates 1 0.844 1994.5 -2565.4  
## + fixed.acidity:density 1 0.787 1994.6 -2565.3  
## + residual.sugar:density 1 0.782 1994.6 -2565.3  
## - volatile.acidity:total.sulfur.dioxide 1 1.259 1996.6 -2565.2  
## - residual.sugar:alcohol 1 1.295 1996.6 -2565.2  
## - fixed.acidity:residual.sugar 1 1.303 1996.7 -2565.2  
## + volatile.acidity:residual.sugar 1 0.706 1994.6 -2565.1  
## + residual.sugar:sulphates 1 0.637 1994.7 -2565.0  
## + chlorides:alcohol 1 0.591 1994.8 -2564.9  
## + fixed.acidity:alcohol 1 0.584 1994.8 -2564.9  
## + sulphates:alcohol 1 0.540 1994.8 -2564.8  
## + fixed.acidity:volatile.acidity 1 0.513 1994.8 -2564.7  
## - pH:alcohol 1 1.535 1996.9 -2564.7  
## + fixed.acidity:chlorides 1 0.482 1994.9 -2564.7  
## - pH:sulphates 1 1.580 1996.9 -2564.6  
## - fixed.acidity:citric.acid 1 1.738 1997.1 -2564.3  
## + fixed.acidity:sulphates 1 0.207 1995.1 -2564.1  
## - fixed.acidity:free.sulfur.dioxide 1 1.853 1997.2 -2564.1  
## + residual.sugar:total.sulfur.dioxide 1 0.177 1995.2 -2564.1  
## + density:pH 1 0.158 1995.2 -2564.0  
## - fixed.acidity:total.sulfur.dioxide 1 1.901 1997.2 -2564.0  
## - citric.acid:residual.sugar 1 1.921 1997.3 -2563.9  
## + citric.acid:alcohol 1 0.109 1995.2 -2563.9  
## + free.sulfur.dioxide:pH 1 0.091 1995.3 -2563.9  
## + chlorides:total.sulfur.dioxide 1 0.088 1995.3 -2563.9  
## + citric.acid:sulphates 1 0.073 1995.3 -2563.9  
## + citric.acid:chlorides 1 0.022 1995.3 -2563.8  
## + volatile.acidity:chlorides 1 0.011 1995.3 -2563.7  
## + citric.acid:free.sulfur.dioxide 1 0.004 1995.3 -2563.7  
## + citric.acid:total.sulfur.dioxide 1 0.003 1995.3 -2563.7  
## + volatile.acidity:free.sulfur.dioxide 1 0.001 1995.3 -2563.7  
## + citric.acid:density 1 0.001 1995.3 -2563.7  
## + total.sulfur.dioxide:alcohol 1 0.000 1995.3 -2563.7  
## + density:sulphates 1 0.000 1995.3 -2563.7  
## + chlorides:free.sulfur.dioxide 1 0.000 1995.3 -2563.7  
## - total.sulfur.dioxide:pH 1 2.401 1997.8 -2563.0  
## - fixed.acidity:pH 1 2.493 1997.8 -2562.8  
## - citric.acid:pH 1 2.813 1998.2 -2562.2  
## - volatile.acidity:pH 1 3.201 1998.5 -2561.4  
## - chlorides:sulphates 1 3.380 1998.7 -2561.1  
## - chlorides:pH 1 3.705 1999.0 -2560.4  
## - residual.sugar:pH 1 3.838 1999.2 -2560.2  
## - free.sulfur.dioxide:density 1 3.955 1999.3 -2560.0  
## - chlorides:density 1 4.234 1999.6 -2559.4  
## - free.sulfur.dioxide:sulphates 1 5.876 2001.2 -2556.2  
## - density:alcohol 1 5.887 2001.2 -2556.2  
## - residual.sugar:chlorides 1 6.898 2002.2 -2554.2  
## - residual.sugar:free.sulfur.dioxide 1 6.943 2002.3 -2554.1  
## - total.sulfur.dioxide:sulphates 1 7.799 2003.2 -2552.4  
## - free.sulfur.dioxide:alcohol 1 8.569 2003.9 -2550.9  
## - volatile.acidity:density 1 9.023 2004.4 -2550.0  
## - volatile.acidity:alcohol 1 30.905 2026.2 -2507.5  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.405 2040.8 -2479.6  
##   
## Step: AIC=-2566  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + volatile.acidity:total.sulfur.dioxide +   
## fixed.acidity:pH + pH:sulphates + total.sulfur.dioxide:pH +   
## fixed.acidity:total.sulfur.dioxide + residual.sugar:alcohol +   
## citric.acid:residual.sugar + fixed.acidity:residual.sugar +   
## volatile.acidity:citric.acid  
##   
## Df Sum of Sq RSS AIC  
## - volatile.acidity:total.sulfur.dioxide 1 0.785 1995.0 -2566.5  
## + residual.sugar:density 1 1.093 1993.1 -2566.2  
## + fixed.acidity:volatile.acidity 1 1.043 1993.1 -2566.1  
## <none> 1994.2 -2566.0  
## + total.sulfur.dioxide:density 1 0.903 1993.3 -2565.8  
## - volatile.acidity:citric.acid 1 1.163 1995.3 -2565.7  
## - residual.sugar:alcohol 1 1.231 1995.4 -2565.6  
## + volatile.acidity:sulphates 1 0.796 1993.4 -2565.6  
## + fixed.acidity:density 1 0.780 1993.4 -2565.5  
## - fixed.acidity:residual.sugar 1 1.352 1995.5 -2565.3  
## + chlorides:alcohol 1 0.625 1993.6 -2565.2  
## + volatile.acidity:residual.sugar 1 0.578 1993.6 -2565.1  
## - fixed.acidity:citric.acid 1 1.467 1995.7 -2565.1  
## + residual.sugar:sulphates 1 0.545 1993.6 -2565.1  
## - pH:alcohol 1 1.501 1995.7 -2565.1  
## + fixed.acidity:alcohol 1 0.521 1993.7 -2565.0  
## + fixed.acidity:chlorides 1 0.452 1993.7 -2564.9  
## + sulphates:alcohol 1 0.451 1993.7 -2564.9  
## - pH:sulphates 1 1.715 1995.9 -2564.6  
## + residual.sugar:total.sulfur.dioxide 1 0.206 1994.0 -2564.4  
## + fixed.acidity:sulphates 1 0.188 1994.0 -2564.4  
## + density:pH 1 0.136 1994.0 -2564.3  
## - fixed.acidity:free.sulfur.dioxide 1 1.924 1996.1 -2564.2  
## + chlorides:total.sulfur.dioxide 1 0.103 1994.1 -2564.2  
## - fixed.acidity:total.sulfur.dioxide 1 1.944 1996.1 -2564.2  
## + free.sulfur.dioxide:pH 1 0.068 1994.1 -2564.1  
## + citric.acid:sulphates 1 0.065 1994.1 -2564.1  
## + citric.acid:alcohol 1 0.042 1994.1 -2564.1  
## + citric.acid:free.sulfur.dioxide 1 0.038 1994.2 -2564.1  
## + citric.acid:density 1 0.023 1994.2 -2564.1  
## + volatile.acidity:chlorides 1 0.022 1994.2 -2564.1  
## + citric.acid:chlorides 1 0.016 1994.2 -2564.0  
## + citric.acid:total.sulfur.dioxide 1 0.008 1994.2 -2564.0  
## + volatile.acidity:free.sulfur.dioxide 1 0.004 1994.2 -2564.0  
## + total.sulfur.dioxide:alcohol 1 0.001 1994.2 -2564.0  
## + chlorides:free.sulfur.dioxide 1 0.001 1994.2 -2564.0  
## + density:sulphates 1 0.000 1994.2 -2564.0  
## - citric.acid:residual.sugar 1 2.267 1996.5 -2563.6  
## - total.sulfur.dioxide:pH 1 2.400 1996.6 -2563.3  
## - fixed.acidity:pH 1 2.501 1996.7 -2563.1  
## - citric.acid:pH 1 2.705 1996.9 -2562.7  
## - chlorides:sulphates 1 3.505 1997.7 -2561.1  
## - chlorides:pH 1 3.660 1997.8 -2560.8  
## - residual.sugar:pH 1 3.710 1997.9 -2560.7  
## - free.sulfur.dioxide:density 1 3.841 1998.0 -2560.5  
## - volatile.acidity:pH 1 3.900 1998.1 -2560.3  
## - chlorides:density 1 4.393 1998.6 -2559.4  
## - density:alcohol 1 5.726 1999.9 -2556.8  
## - free.sulfur.dioxide:sulphates 1 5.790 2000.0 -2556.6  
## - residual.sugar:free.sulfur.dioxide 1 6.781 2001.0 -2554.7  
## - residual.sugar:chlorides 1 7.046 2001.2 -2554.2  
## - total.sulfur.dioxide:sulphates 1 7.654 2001.8 -2553.0  
## - volatile.acidity:density 1 7.693 2001.9 -2552.9  
## - free.sulfur.dioxide:alcohol 1 8.514 2002.7 -2551.3  
## - volatile.acidity:alcohol 1 29.189 2023.4 -2511.1  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.262 2039.5 -2480.1  
##   
## Step: AIC=-2566.46  
## quality ~ fixed.acidity + volatile.acidity + citric.acid + residual.sugar +   
## chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + fixed.acidity:pH + pH:sulphates +   
## total.sulfur.dioxide:pH + fixed.acidity:total.sulfur.dioxide +   
## residual.sugar:alcohol + citric.acid:residual.sugar + fixed.acidity:residual.sugar +   
## volatile.acidity:citric.acid  
##   
## Df Sum of Sq RSS AIC  
## <none> 1995.0 -2566.5  
## + total.sulfur.dioxide:density 1 0.901 1994.1 -2566.2  
## + fixed.acidity:volatile.acidity 1 0.866 1994.1 -2566.2  
## - fixed.acidity:residual.sugar 1 1.235 1996.2 -2566.0  
## + volatile.acidity:total.sulfur.dioxide 1 0.785 1994.2 -2566.0  
## - residual.sugar:alcohol 1 1.297 1996.3 -2565.9  
## + residual.sugar:density 1 0.700 1994.3 -2565.8  
## + fixed.acidity:density 1 0.690 1994.3 -2565.8  
## + chlorides:alcohol 1 0.627 1994.3 -2565.7  
## + volatile.acidity:residual.sugar 1 0.627 1994.3 -2565.7  
## - fixed.acidity:citric.acid 1 1.412 1996.4 -2565.7  
## - pH:alcohol 1 1.443 1996.4 -2565.6  
## + residual.sugar:sulphates 1 0.562 1994.4 -2565.6  
## + fixed.acidity:alcohol 1 0.469 1994.5 -2565.4  
## + volatile.acidity:sulphates 1 0.436 1994.5 -2565.3  
## + fixed.acidity:chlorides 1 0.428 1994.5 -2565.3  
## + sulphates:alcohol 1 0.422 1994.5 -2565.3  
## - volatile.acidity:citric.acid 1 1.637 1996.6 -2565.2  
## - fixed.acidity:free.sulfur.dioxide 1 1.729 1996.7 -2565.1  
## - pH:sulphates 1 1.735 1996.7 -2565.1  
## + residual.sugar:total.sulfur.dioxide 1 0.200 1994.8 -2564.8  
## + volatile.acidity:free.sulfur.dioxide 1 0.182 1994.8 -2564.8  
## + density:pH 1 0.170 1994.8 -2564.8  
## + fixed.acidity:sulphates 1 0.149 1994.8 -2564.8  
## + free.sulfur.dioxide:pH 1 0.114 1994.9 -2564.7  
## + volatile.acidity:chlorides 1 0.075 1994.9 -2564.6  
## + chlorides:total.sulfur.dioxide 1 0.056 1994.9 -2564.6  
## + citric.acid:total.sulfur.dioxide 1 0.051 1994.9 -2564.6  
## + citric.acid:sulphates 1 0.031 1994.9 -2564.5  
## + citric.acid:density 1 0.029 1994.9 -2564.5  
## + citric.acid:alcohol 1 0.020 1995.0 -2564.5  
## + citric.acid:free.sulfur.dioxide 1 0.015 1995.0 -2564.5  
## + citric.acid:chlorides 1 0.013 1995.0 -2564.5  
## + total.sulfur.dioxide:alcohol 1 0.004 1995.0 -2564.5  
## + density:sulphates 1 0.000 1995.0 -2564.5  
## + chlorides:free.sulfur.dioxide 1 0.000 1995.0 -2564.5  
## - fixed.acidity:total.sulfur.dioxide 1 2.133 1997.1 -2564.3  
## - citric.acid:residual.sugar 1 2.453 1997.4 -2563.7  
## - fixed.acidity:pH 1 2.470 1997.4 -2563.6  
## - citric.acid:pH 1 2.614 1997.6 -2563.3  
## - total.sulfur.dioxide:pH 1 2.648 1997.6 -2563.3  
## - chlorides:sulphates 1 3.340 1998.3 -2561.9  
## - chlorides:pH 1 3.655 1998.6 -2561.3  
## - residual.sugar:pH 1 3.883 1998.8 -2560.8  
## - volatile.acidity:pH 1 4.038 1999.0 -2560.5  
## - chlorides:density 1 4.439 1999.4 -2559.8  
## - free.sulfur.dioxide:density 1 4.608 1999.6 -2559.4  
## - free.sulfur.dioxide:sulphates 1 5.329 2000.3 -2558.0  
## - density:alcohol 1 6.003 2001.0 -2556.7  
## - residual.sugar:chlorides 1 7.101 2002.1 -2554.5  
## - residual.sugar:free.sulfur.dioxide 1 7.534 2002.5 -2553.7  
## - total.sulfur.dioxide:sulphates 1 7.538 2002.5 -2553.7  
## - free.sulfur.dioxide:alcohol 1 9.802 2004.8 -2549.3  
## - volatile.acidity:density 1 9.924 2004.9 -2549.0  
## - volatile.acidity:alcohol 1 28.444 2023.4 -2513.0  
## - free.sulfur.dioxide:total.sulfur.dioxide 1 45.408 2040.4 -2480.3

# \* 항 포함한 내용  
summary(model.AIC2)

##   
## Call:  
## lm(formula = quality ~ fixed.acidity + volatile.acidity + citric.acid +   
## residual.sugar + chlorides + free.sulfur.dioxide + total.sulfur.dioxide +   
## density + pH + sulphates + alcohol + free.sulfur.dioxide:total.sulfur.dioxide +   
## volatile.acidity:alcohol + residual.sugar:free.sulfur.dioxide +   
## pH:alcohol + fixed.acidity:citric.acid + fixed.acidity:free.sulfur.dioxide +   
## density:alcohol + volatile.acidity:density + free.sulfur.dioxide:alcohol +   
## chlorides:sulphates + residual.sugar:pH + free.sulfur.dioxide:density +   
## citric.acid:pH + residual.sugar:chlorides + chlorides:density +   
## total.sulfur.dioxide:sulphates + free.sulfur.dioxide:sulphates +   
## chlorides:pH + volatile.acidity:pH + fixed.acidity:pH + pH:sulphates +   
## total.sulfur.dioxide:pH + fixed.acidity:total.sulfur.dioxide +   
## residual.sugar:alcohol + citric.acid:residual.sugar + fixed.acidity:residual.sugar +   
## volatile.acidity:citric.acid, data = train)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -3.3875 -0.4905 -0.0100 0.4392 3.0370   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)  
## (Intercept) 1.556e+02 9.683e+01 1.607 0.108088  
## fixed.acidity -4.118e-01 3.035e-01 -1.357 0.174901  
## volatile.acidity -1.944e+02 4.074e+01 -4.772 1.89e-06  
## citric.acid -4.085e+00 2.819e+00 -1.449 0.147492  
## residual.sugar 2.560e-01 8.774e-02 2.918 0.003548  
## chlorides -1.443e+03 5.078e+02 -2.842 0.004510  
## free.sulfur.dioxide -3.451e+00 1.136e+00 -3.037 0.002404  
## total.sulfur.dioxide 3.455e-02 9.944e-03 3.474 0.000518  
## density -1.429e+02 9.744e+01 -1.467 0.142498  
## pH -2.256e+00 1.352e+00 -1.669 0.095259  
## sulphates -1.755e+00 2.126e+00 -0.826 0.409057  
## alcohol 2.335e+01 7.065e+00 3.305 0.000958  
## free.sulfur.dioxide:total.sulfur.dioxide -8.716e-05 9.276e-06 -9.396 < 2e-16  
## volatile.acidity:alcohol 8.156e-01 1.097e-01 7.437 1.26e-13  
## residual.sugar:free.sulfur.dioxide -1.670e-03 4.363e-04 -3.827 0.000132  
## pH:alcohol 1.475e-01 8.810e-02 1.675 0.094051  
## fixed.acidity:citric.acid -2.162e-01 1.305e-01 -1.657 0.097604  
## fixed.acidity:free.sulfur.dioxide 2.283e-03 1.245e-03 1.834 0.066764  
## density:alcohol -2.436e+01 7.129e+00 -3.417 0.000641  
## volatile.acidity:density 1.769e+02 4.028e+01 4.393 1.15e-05  
## free.sulfur.dioxide:alcohol 6.748e-03 1.546e-03 4.366 1.30e-05  
## chlorides:sulphates -1.404e+01 5.507e+00 -2.549 0.010856  
## residual.sugar:pH -5.453e-02 1.984e-02 -2.748 0.006028  
## free.sulfur.dioxide:density 3.403e+00 1.137e+00 2.993 0.002777  
## citric.acid:pH 1.667e+00 7.396e-01 2.254 0.024235  
## residual.sugar:chlorides -9.631e-01 2.592e-01 -3.716 0.000205  
## chlorides:density 1.503e+03 5.116e+02 2.938 0.003326  
## total.sulfur.dioxide:sulphates -1.259e-02 3.289e-03 -3.829 0.000131  
## free.sulfur.dioxide:sulphates 2.287e-02 7.104e-03 3.219 0.001297  
## chlorides:pH -1.288e+01 4.833e+00 -2.666 0.007711  
## volatile.acidity:pH 2.424e+00 8.650e-01 2.802 0.005104  
## fixed.acidity:pH 2.024e-01 9.236e-02 2.192 0.028460  
## pH:sulphates 1.208e+00 6.577e-01 1.837 0.066354  
## total.sulfur.dioxide:pH -5.960e-03 2.627e-03 -2.269 0.023331  
## fixed.acidity:total.sulfur.dioxide -9.405e-04 4.618e-04 -2.037 0.041759  
## residual.sugar:alcohol 6.733e-03 4.239e-03 1.588 0.112302  
## citric.acid:residual.sugar -4.221e-02 1.933e-02 -2.184 0.029023  
## fixed.acidity:residual.sugar 5.551e-03 3.581e-03 1.550 0.121261  
## volatile.acidity:citric.acid 1.551e+00 8.696e-01 1.784 0.074528  
##   
## (Intercept)   
## fixed.acidity   
## volatile.acidity \*\*\*  
## citric.acid   
## residual.sugar \*\*   
## chlorides \*\*   
## free.sulfur.dioxide \*\*   
## total.sulfur.dioxide \*\*\*  
## density   
## pH .   
## sulphates   
## alcohol \*\*\*  
## free.sulfur.dioxide:total.sulfur.dioxide \*\*\*  
## volatile.acidity:alcohol \*\*\*  
## residual.sugar:free.sulfur.dioxide \*\*\*  
## pH:alcohol .   
## fixed.acidity:citric.acid .   
## fixed.acidity:free.sulfur.dioxide .   
## density:alcohol \*\*\*  
## volatile.acidity:density \*\*\*  
## free.sulfur.dioxide:alcohol \*\*\*  
## chlorides:sulphates \*   
## residual.sugar:pH \*\*   
## free.sulfur.dioxide:density \*\*   
## citric.acid:pH \*   
## residual.sugar:chlorides \*\*\*  
## chlorides:density \*\*   
## total.sulfur.dioxide:sulphates \*\*\*  
## free.sulfur.dioxide:sulphates \*\*   
## chlorides:pH \*\*   
## volatile.acidity:pH \*\*   
## fixed.acidity:pH \*   
## pH:sulphates .   
## total.sulfur.dioxide:pH \*   
## fixed.acidity:total.sulfur.dioxide \*   
## residual.sugar:alcohol   
## citric.acid:residual.sugar \*   
## fixed.acidity:residual.sugar   
## volatile.acidity:citric.acid .   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.7171 on 3879 degrees of freedom  
## Multiple R-squared: 0.3509, Adjusted R-squared: 0.3445   
## F-statistic: 55.17 on 38 and 3879 DF, p-value: < 2.2e-16

test$pred\_AIC2 <- predict(model.AIC2, newdata = test)  
rmse(test$quality, test$pred\_AIC2)

## [1] 0.7178999