Peer-graded Assignment: Regression Models Course Project

Introduction: You work for Motor Trend, a magazine about the automobile industry. Looking at a data set of a collection of cars, they are interested in exploring the relationship between a set of variables and miles per gallon (MPG) (outcome). They are particularly interested in the following two questions:

1. Is an automatic or manual transmission better for MPG
2. Quantify the MPG difference between automatic and manual transmissions

1 Load the mtcars data and perform some basic exploratory data analyses.

According to description, the data contains 32 observations on 11 (numeric) variables.

1. mpg Miles/(US) gallon
2. cyl Number of cylinders
3. disp Displacement (cu.in.)
4. hp Gross horsepower
5. drat Rear axle ratio
6. wt Weight (1000 lbs)
7. qsec 1/4 mile time
8. vs Engine (0 = V-shaped, 1 = straight)
9. am Transmission (0 = automatic, 1 = manual)
10. gear Number of forward gears
11. carb Number of carburetors

```
# Load data
data(mtcars)

# Preview data structure
str(mtcars)
```

```
## 'data.frame':    32 obs. of  11 variables:
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
```

```
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
##  $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

2. Provide a basic summary of the data.

Here provides the basic summaries for automatic and manual transmission

```
# Summary for the automatic transmission
summary(mtcars[mtcars$am==0,])
```

```
##       mpg             cyl             disp             hp
##  Min.   :10.40   Min.   :4.000   Min.   :120.1   Min.   : 62.0
##  1st Qu.:14.95   1st Qu.:6.000   1st Qu.:196.3   1st Qu.:116.5
##  Median :17.30   Median :8.000   Median :275.8   Median :175.0
##  Mean   :17.15   Mean   :6.947   Mean   :290.4   Mean   :160.3
##  3rd Qu.:19.20   3rd Qu.:8.000   3rd Qu.:360.0   3rd Qu.:192.5
##  Max.   :24.40   Max.   :8.000   Max.   :472.0   Max.   :245.0
##       drat             wt             qsec             vs               am
##  Min.   :2.760   Min.   :2.465   Min.   :15.41   Min.   :0.0000   Min.   :0
##  1st Qu.:3.070   1st Qu.:3.438   1st Qu.:17.18   1st Qu.:0.0000   1st Qu.:0
##  Median :3.150   Median :3.520   Median :17.82   Median :0.0000   Median :0
##  Mean   :3.286   Mean   :3.769   Mean   :18.18   Mean   :0.3684   Mean   :0
##  3rd Qu.:3.695   3rd Qu.:3.842   3rd Qu.:19.17   3rd Qu.:1.0000   3rd Qu.:0
##  Max.   :3.920   Max.   :5.424   Max.   :22.90   Max.   :1.0000   Max.   :0
##       gear            carb
##  Min.   :3.000   Min.   :1.000
##  1st Qu.:3.000   1st Qu.:2.000
##  Median :3.000   Median :3.000
##  Mean   :3.211   Mean   :2.737
##  3rd Qu.:3.000   3rd Qu.:4.000
##  Max.   :4.000   Max.   :4.000
```

```r
# Summary for the manual transmission
summary(mtcars[mtcars$am==1,])
```

```
##       mpg             cyl             disp             hp             drat      
##  Min.   :15.00   Min.   :4.000   Min.   : 71.1   Min.   : 52.0   Min.   :3.54  
##  1st Qu.:21.00   1st Qu.:4.000   1st Qu.: 79.0   1st Qu.: 66.0   1st Qu.:3.85  
##  Median :22.80   Median :4.000   Median :120.3   Median :109.0   Median :4.08  
##  Mean   :24.39   Mean   :5.077   Mean   :143.5   Mean   :126.8   Mean   :4.05  
##  3rd Qu.:30.40   3rd Qu.:6.000   3rd Qu.:160.0   3rd Qu.:113.0   3rd Qu.:4.22  
##  Max.   :33.90   Max.   :8.000   Max.   :351.0   Max.   :335.0   Max.   :4.93  
##        wt             qsec             vs               am          gear      
##  Min.   :1.513   Min.   :14.50   Min.   :0.0000   Min.   :1   Min.   :4.000  
##  1st Qu.:1.935   1st Qu.:16.46   1st Qu.:0.0000   1st Qu.:1   1st Qu.:4.000  
##  Median :2.320   Median :17.02   Median :1.0000   Median :1   Median :4.000  
##  Mean   :2.411   Mean   :17.36   Mean   :0.5385   Mean   :1   Mean   :4.385  
##  3rd Qu.:2.780   3rd Qu.:18.61   3rd Qu.:1.0000   3rd Qu.:1   3rd Qu.:5.000  
##  Max.   :3.570   Max.   :19.90   Max.   :1.0000   Max.   :1   Max.   :5.000  
##       carb      
##  Min.   :1.000  
##  1st Qu.:1.000  
##  Median :2.000  
##  Mean   :2.923  
##  3rd Qu.:4.000  
##  Max.   :8.000
```

There is also a multivariable comparison chart and a boxplot "Miles/(US) gallon by different transmissions" in Appendix A.

3. Model Selection

We applied the backward selection approach to fit our model. This is a method, which slowly remove one term at a time, starting with the term with the highest p-value.

We took out the term with the highest p-value if its p-value were higher than above a specified p-value threshold (5%). We updated the model and check the term with the highest P-value. This continued until all the remaining terms that were included in the model were below a specified p-value threshold.

```r
# Initial our model with all terms
fit <- lm(mpg ~ . , data = mtcars)
# Show initial P-values
summary(fit)$coef
```

```
##                Estimate  Std. Error    t value   Pr(>|t|)
## (Intercept) 12.30337416 18.71788443  0.6573058 0.51812440
## cyl         -0.11144048  1.04502336 -0.1066392 0.91608738
## disp         0.01333524  0.01785750  0.7467585 0.46348865
## hp          -0.02148212  0.02176858 -0.9868407 0.33495531
## drat         0.78711097  1.63537307  0.4813036 0.63527790
## wt          -3.71530393  1.89441430 -1.9611887 0.06325215
## qsec         0.82104075  0.73084480  1.1234133 0.27394127
## vs           0.31776281  2.10450861  0.1509915 0.88142347
## am           2.52022689  2.05665055  1.2254035 0.23398971
## gear         0.65541302  1.49325996  0.4389142 0.66520643
## carb        -0.19941925  0.82875250 -0.2406258 0.81217871
```

```r
# Start the backward selection approach
require(MASS)
step <- stepAIC(fit, direction="backward")
```

Steps can be found in the Appendix A.

```r
step$anova # display results
```

```
## Stepwise Model Path
## Analysis of Deviance Table
##
## Initial Model:
## mpg ~ cyl + disp + hp + drat + wt + qsec + vs + am + gear + carb
##
## Final Model:
## mpg ~ wt + qsec + am
##
##
##     Step Df   Deviance Resid. Df Resid. Dev      AIC
```

```
## 1                           21   147.4944 70.89774
## 2  - cyl  1 0.07987121       22   147.5743 68.91507
## 3   - vs  1 0.26852280       23   147.8428 66.97324
## 4 - carb  1 0.68546077       24   148.5283 65.12126
## 5 - gear  1 1.56497053       25   150.0933 63.45667
## 6 - drat  1 3.34455117       26   153.4378 62.16190
## 7 - disp  1 6.62865369       27   160.0665 61.51530
## 8   - hp  1 9.21946935       28   169.2859 61.30730
```

```
# Update our model
fit <- update(fit, mpg ~ wt + qsec + am, data = mtcars)
# Show final P-values
summary(fit)$coef
```

```
##              Estimate Std. Error   t value     Pr(>|t|)
## (Intercept)  9.617781  6.9595930  1.381946 1.779152e-01
## wt          -3.916504  0.7112016 -5.506882 6.952711e-06
## qsec         1.225886  0.2886696  4.246676 2.161737e-04
## am           2.935837  1.4109045  2.080819 4.671551e-02
```

4 Model diagnostics

We diagnosed our model by the variance inflation factor(VIF). The VIF estimates how much the variance of a regression coefficient is inflated due to multicollinearity in the model.If VIF values were greater than 10, it indicated that terms were highly collinear with the other terms in the model.

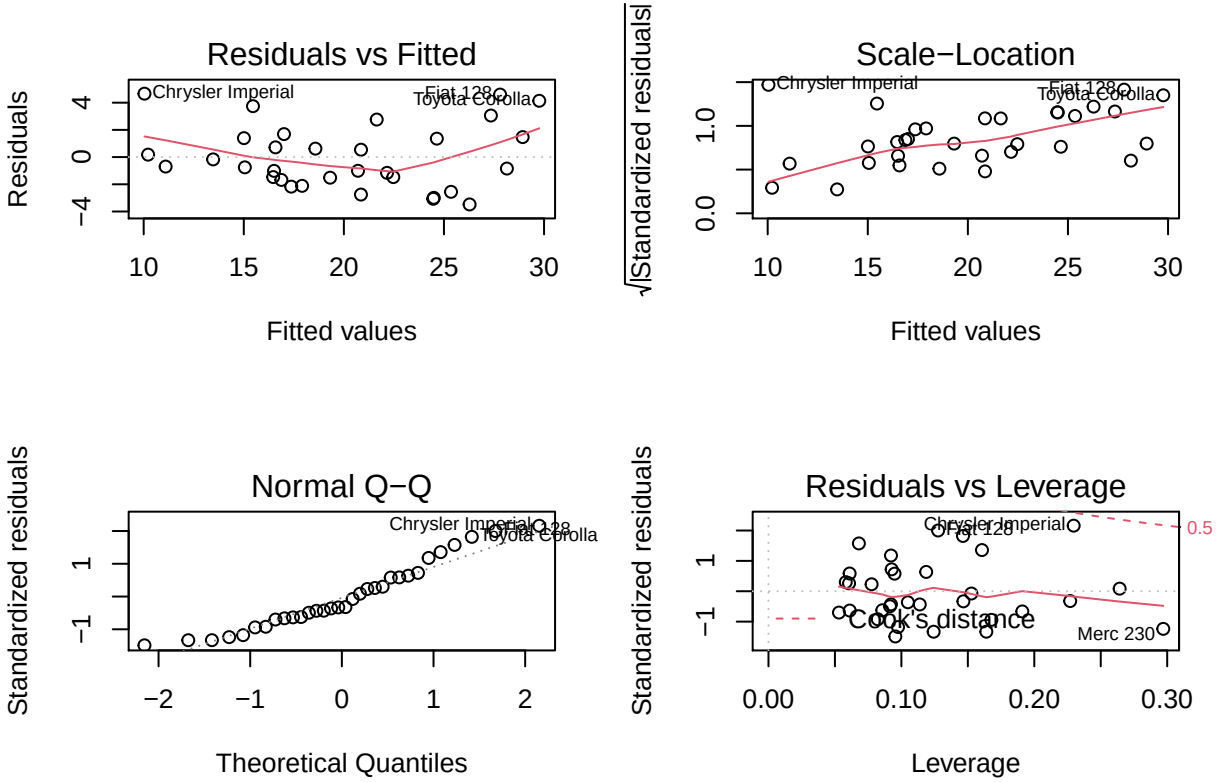
```
library(car)
vif(fit)
```

```
##       wt     qsec       am
## 2.482952 1.364339 2.541437
```

The result of VIF was satisfactory.

We also used diagnostic plots to provide checks for heteroscedasticity, normality, and influential observerations.

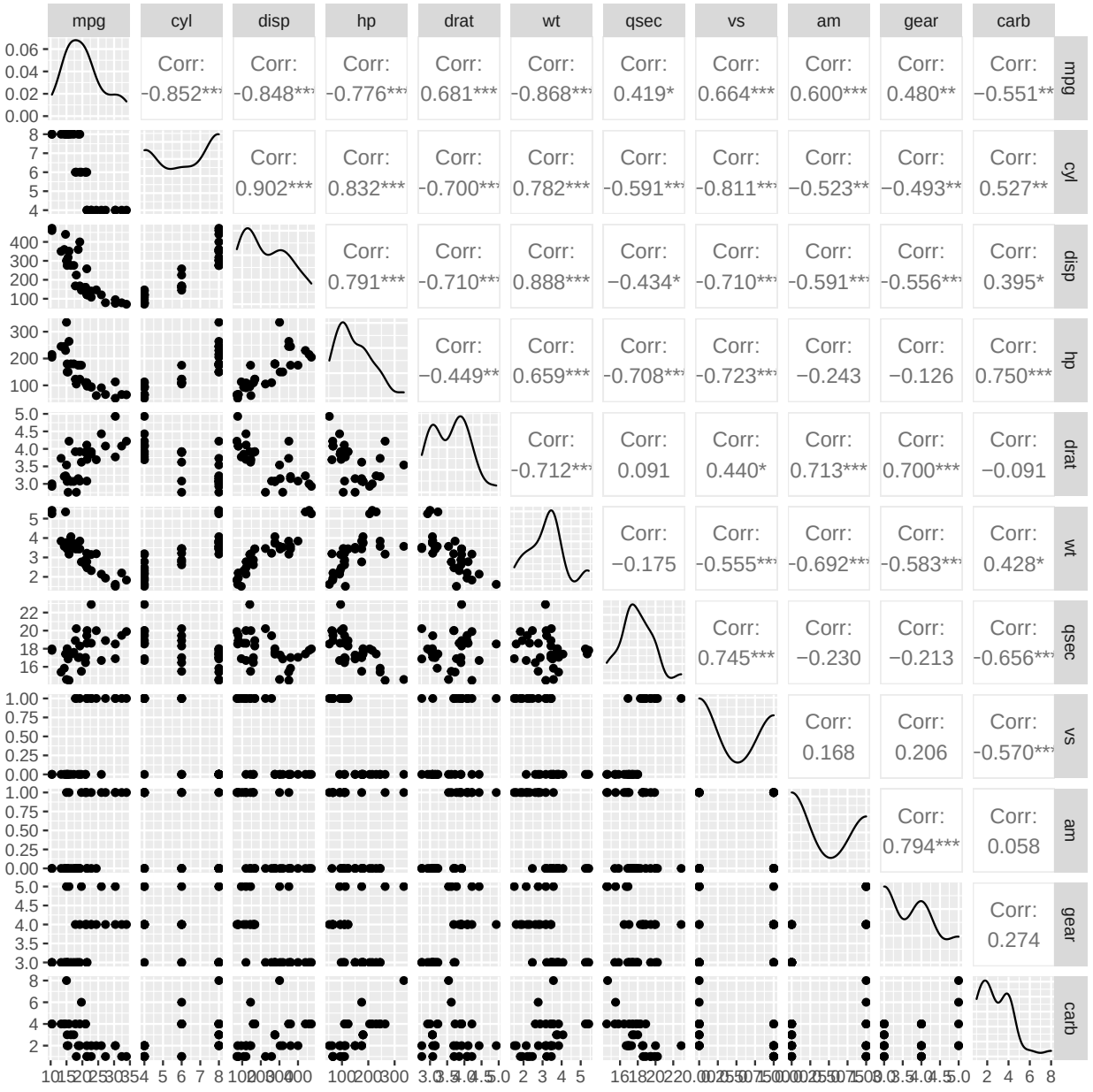
```
# diagnostic plots
layout(matrix(c(1,2,3,4),2,2)) # optional 4 graphs/page
plot(fit)
```



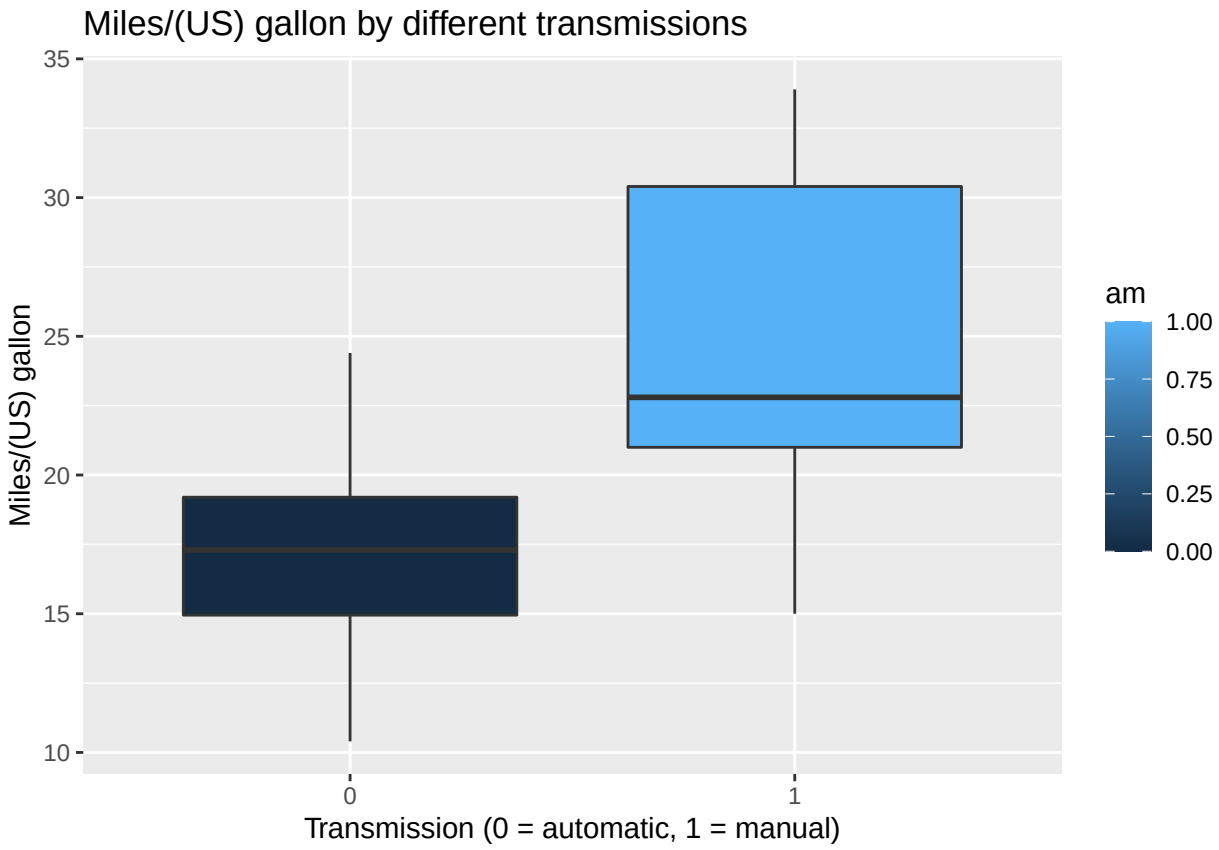
The plots showed that there was no a very clear systematic pattern in our residuals.

Appendix A

```
require(GGally)
# Multivariable Comparison
g <- ggpairs(mtcars)
g
```


mpg
cyl
disp
hp
drat
wt
qsec
vs
am
gear
carb
Corr: -0.852***
Corr: -0.848***
Corr: -0.776***
Corr: 0.681***
Corr: -0.868***
Corr: 0.419*
Corr: 0.664***
Corr: 0.600***
Corr: 0.480**
Corr: −0.551**
Corr: 0.902***
Corr: 0.832***
Corr: -0.700***
Corr: 0.782***
Corr: -0.591***
Corr: -0.811***
Corr: −0.523**
Corr: −0.493**
Corr: 0.527**
Corr: 0.791***
Corr: -0.710***
Corr: 0.888***
Corr: −0.434*
Corr: -0.710***
Corr: -0.591***
Corr: -0.556***
Corr: 0.395*
Corr: −0.449**
Corr: 0.659***
Corr: -0.708***
Corr: -0.723***
Corr: −0.243
Corr: −0.126
Corr: 0.750***
Corr: -0.712***
Corr: 0.091
Corr: 0.440*
Corr: 0.713***
Corr: 0.700***
Corr: −0.091
Corr: −0.175
Corr: -0.555***
Corr: -0.692***
Corr: -0.583***
Corr: 0.428*
Corr: 0.745***
Corr: −0.230
Corr: −0.213
Corr: -0.656***
Corr: 0.168
Corr: 0.206
Corr: -0.570***
Corr: 0.794***
Corr: 0.058
Corr: 0.274

```r
# Preview data by a boxplot
require(ggplot2)
g2 <- ggplot(mtcars, aes(x = factor(am), y = mpg, fill = am)) +
    geom_boxplot() +
    ggtitle("Miles/(US) gallon by different transmissions") +
    scale_x_discrete("Transmission (0 = automatic, 1 = manual)") +
    scale_y_continuous("Miles/(US) gallon")
g2
```



Appendix B

```r
fit <- lm(mpg ~ . , data = mtcars)
# Start the backward selection approach
require(MASS)
step <- stepAIC(fit, direction="backward")
```

```
## Start:  AIC=70.9
## mpg ~ cyl + disp + hp + drat + wt + qsec + vs + am + gear + carb
##
##        Df Sum of Sq    RSS    AIC
## - cyl   1    0.0799 147.57 68.915
## - vs    1    0.1601 147.66 68.932
## - carb  1    0.4067 147.90 68.986
## - gear  1    1.3531 148.85 69.190
## - drat  1    1.6270 149.12 69.249
## - disp  1    3.9167 151.41 69.736
## - hp    1    6.8399 154.33 70.348
## - qsec  1    8.8641 156.36 70.765
## <none>              147.49 70.898
## - am    1   10.5467 158.04 71.108
## - wt    1   27.0144 174.51 74.280
##
## Step:  AIC=68.92
## mpg ~ disp + hp + drat + wt + qsec + vs + am + gear + carb
##
##        Df Sum of Sq    RSS    AIC
## - vs    1    0.2685 147.84 66.973
## - carb  1    0.5201 148.09 67.028
## - gear  1    1.8211 149.40 67.308
## - drat  1    1.9826 149.56 67.342
## - disp  1    3.9009 151.47 67.750
## - hp    1    7.3632 154.94 68.473
## <none>              147.57 68.915
## - qsec  1   10.0933 157.67 69.032
## - am    1   11.8359 159.41 69.384
## - wt    1   27.0280 174.60 72.297
##
```

```
## Step:  AIC=66.97
## mpg ~ disp + hp + drat + wt + qsec + am + gear + carb
##
##        Df Sum of Sq    RSS    AIC
## - carb  1    0.6855 148.53 65.121
## - gear  1    2.1437 149.99 65.434
## - drat  1    2.2139 150.06 65.449
## - disp  1    3.6467 151.49 65.753
## - hp    1    7.1060 154.95 66.475
## <none>              147.84 66.973
## - am    1   11.5694 159.41 67.384
## - qsec  1   15.6830 163.53 68.200
## - wt    1   27.3799 175.22 70.410
##
## Step:  AIC=65.12
## mpg ~ disp + hp + drat + wt + qsec + am + gear
##
##        Df Sum of Sq    RSS    AIC
## - gear  1     1.565 150.09 63.457
## - drat  1     1.932 150.46 63.535
## <none>              148.53 65.121
## - disp  1    10.110 158.64 65.229
## - am    1    12.323 160.85 65.672
## - hp    1    14.826 163.35 66.166
## - qsec  1    26.408 174.94 68.358
## - wt    1    69.127 217.66 75.350
##
## Step:  AIC=63.46
## mpg ~ disp + hp + drat + wt + qsec + am
##
##        Df Sum of Sq    RSS    AIC
## - drat  1     3.345 153.44 62.162
## - disp  1     8.545 158.64 63.229
## <none>              150.09 63.457
## - hp    1    13.285 163.38 64.171
## - am    1    20.036 170.13 65.466
## - qsec  1    25.574 175.67 66.491
## - wt    1    67.572 217.66 73.351
##
```

```
## Step:  AIC=62.16
## mpg ~ disp + hp + wt + qsec + am
##
##        Df Sum of Sq    RSS    AIC
## - disp  1     6.629 160.07 61.515
## <none>              153.44 62.162
## - hp    1    12.572 166.01 62.682
## - qsec  1    26.470 179.91 65.255
## - am    1    32.198 185.63 66.258
## - wt    1    69.043 222.48 72.051
##
## Step:  AIC=61.52
## mpg ~ hp + wt + qsec + am
##
##        Df Sum of Sq    RSS    AIC
## - hp    1     9.219 169.29 61.307
## <none>              160.07 61.515
## - qsec  1    20.225 180.29 63.323
## - am    1    25.993 186.06 64.331
## - wt    1    78.494 238.56 72.284
##
## Step:  AIC=61.31
## mpg ~ wt + qsec + am
##
##        Df Sum of Sq    RSS    AIC
## <none>              169.29 61.307
## - am    1    26.178 195.46 63.908
## - qsec  1   109.034 278.32 75.217
## - wt    1   183.347 352.63 82.790
```