Analysis of MPG vs Transmission

Eric Scuccimarra

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Executive Summary

The objective is to analyze the data from the 1974 Motor Trend road tests of cars to determine if there is a relationship between type of transmission and miles per gallon. To accomplish this multiple linear models are fitted and examined. The best fitting model includes three regressors - weight, quarter mile time and transmission type. In this model manual transmission provides a 2.9 MPG advantage over automatic transmissions.

Loading and Preprocessing Data

The data is part of R's datasets library and is loaded as follows:

```
library(datasets)
data(mtcars)
mtcars$am <- as.factor(mtcars$am)
levels(mtcars$am) <- c("Automatic", "Manual")
mtcars$cyl <- as.factor(mtcars$cyl)
mtcars$gear <- NULL
```

The data was preprocessed by converting transmission type and number of cylinders to factors and removing the number of gears as that only is relevant to manual cars.

Exploratory Analysis

The boxplot comparing MPG by transmission type, included in the Appendix, indicates that there is a strong correlation between transmission type and MPG, with manual having not only a higher median, but also having a higher 1st quartile than the 3rd quartile of automatics.

However almost all of the variables in the data appear to be correlated with MPG, with the most significant correlation existing between MPG and weight, cylinders, displacement and horsepower, in order of descending correlation. The correlation of the variables to MPG is included in the appendix.

To get a baseline I fit a model between mpg and transmission.

```
fit0 <- lm(mpg ~ am, data = mtcars)
summary(fit0)$coef
```

```
##              Estimate Std. Error   t value     Pr(>|t|)
## (Intercept) 17.147368   1.124603 15.247492 1.133983e-15
## amManual     7.244939   1.764422  4.106127 2.850207e-04
```

```
summary(fit0)$r.squared
```

```
## [1] 0.3597989
```

The R^2 of this model indicates that it explains only 36% of the variability in MPG, which is to be expected given the fact that a two-level factor is being asked to explain a wide range of MPG values. A diagnostic plot of this model is included in the appendix.

Regression Analysis

I will use the step function in the MASS library which will automate selection of a model using the AIC step-wise algorithm. The AIC starts with a model comparing all variables and then tests and compares subsets of that model, returning the best fitting model.

```
library(MASS)
fit1 <- lm(mpg ~ ., data=mtcars)
sfit1 <- step(fit1, direction="both")
```

```
summary(sfit1)
```

```
##
## Call:
## lm(formula = mpg ~ wt + qsec + am, data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.4811 -1.5555 -0.7257  1.4110  4.6610
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept)   9.6178     6.9596   1.382 0.177915
## wt           -3.9165     0.7112  -5.507 6.95e-06 ***
## qsec          1.2259     0.2887   4.247 0.000216 ***
## amManual      2.9358     1.4109   2.081 0.046716 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.459 on 28 degrees of freedom
## Multiple R-squared:  0.8497, Adjusted R-squared:  0.8336
## F-statistic: 52.75 on 3 and 28 DF,  p-value: 1.21e-11
```

Step has chosen weight + quarter mile time plus transmission type as the best model, which explains 85% of the variability in MPG. The ANOVA output of the step command is included in the appendix.

The diagnostic plots for this model are included in the appendix but there are a few notable concerns raised by them. - The Q-Q plot deviates from the diagonal, indicating non-normal data. - The Residuals vs Fitted line is skewed.

This raised enough doubts in my mind that I manually tried to fit a few other models to compare. For the sake of brevity those attempts are not included in this document. None of the models fit as well as the model selected by step.

```
mmanual <- mean(subset(mtcars, am == "Manual")$wt)
mauto <- mean(subset(mtcars, am == "Automatic")$wt)
```

One notable caveat is that there is a substantial difference in the mean weights between manual and automatic cars. The mean weight of manual cars is 2.411 while the mean weight of automatic cars is 3.7688947. This makes it difficult to judge how much of the difference in MPG is due to the transmission and how much is due to the extra weight of automatic automobiles.

This is accounted for in the summary of the model above, where significance of including the transmission type in the model is dangerously close to the 0.05 cutoff, with a Pr(>t) of 0.467.

Conclusion

Disregarding other variables manual tranmission provides a 7.2 MPG advantage over automatic transmission. Our best fit model includes weight, quarter mile time and transmission type with manual transmission with manual transmission providing an average 2.9 MPG gain over automatic transmission.

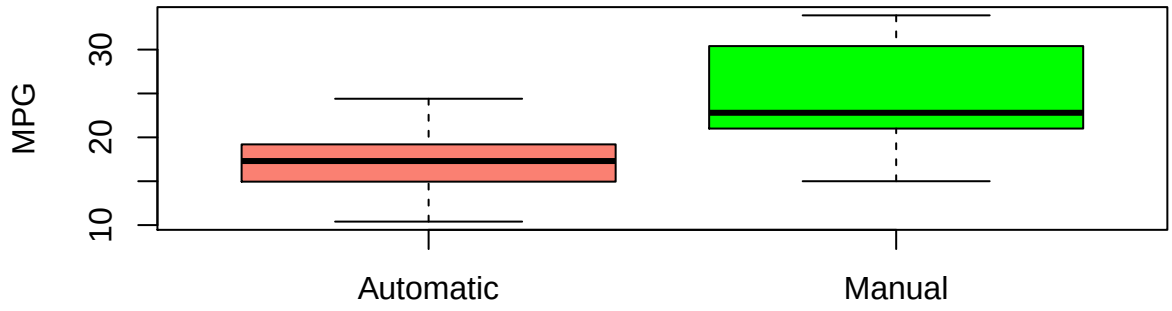
The feature most correlated to the MPG is the weight of the vehicle, which is also highly correlated to the transmission type. While the model include the transmission type does provide a better fit, the significance of adding the transmission type variable is close enough to the 5% threshhold that I cannot confidently assert that the difference in MPG between automatic and manual transmissions is not due to the extra weight associated with automatic transmissions without additional data.

I should also stress that this data is from 1974 so may not be relevant to modern automobiles.

Appendix

Boxplot of MPG vs Transmission

```
boxplot(mtcars$mpg ~ mtcars$am, col=c("salmon","green"), ylab="MPG")
```



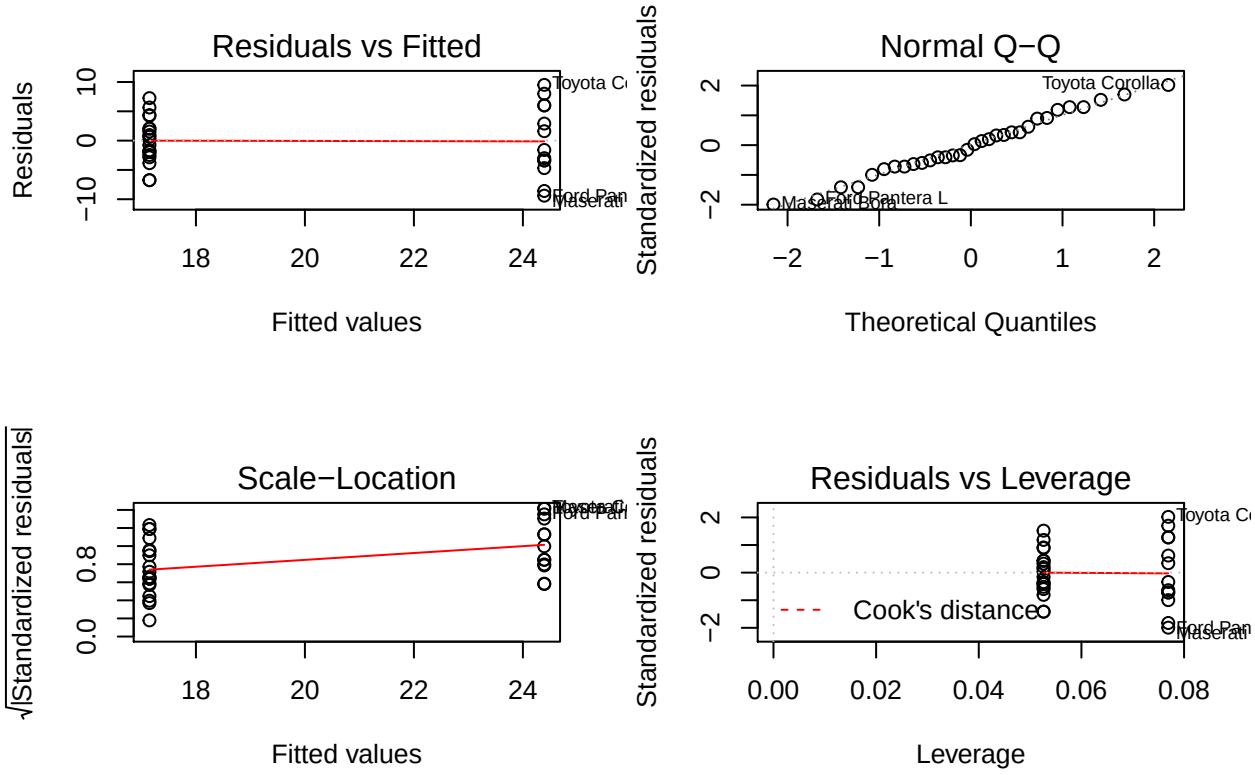
Correlation Matrix for Data

```
data(mtcars)
mtcars$gear <- NULL
apply(mtcars, 2, function(col) cor(col, mtcars$mpg))
```

```
##        mpg        cyl       disp         hp       drat         wt
##  1.0000000 -0.8521620 -0.8475514 -0.7761684  0.6811719 -0.8676594
##       qsec         vs         am       carb
##  0.4186840  0.6640389  0.5998324 -0.5509251
```

Diagnostic plot of fit between MPG and transmission

```
par(mfrow=c(2,2))
plot(fit0)
```



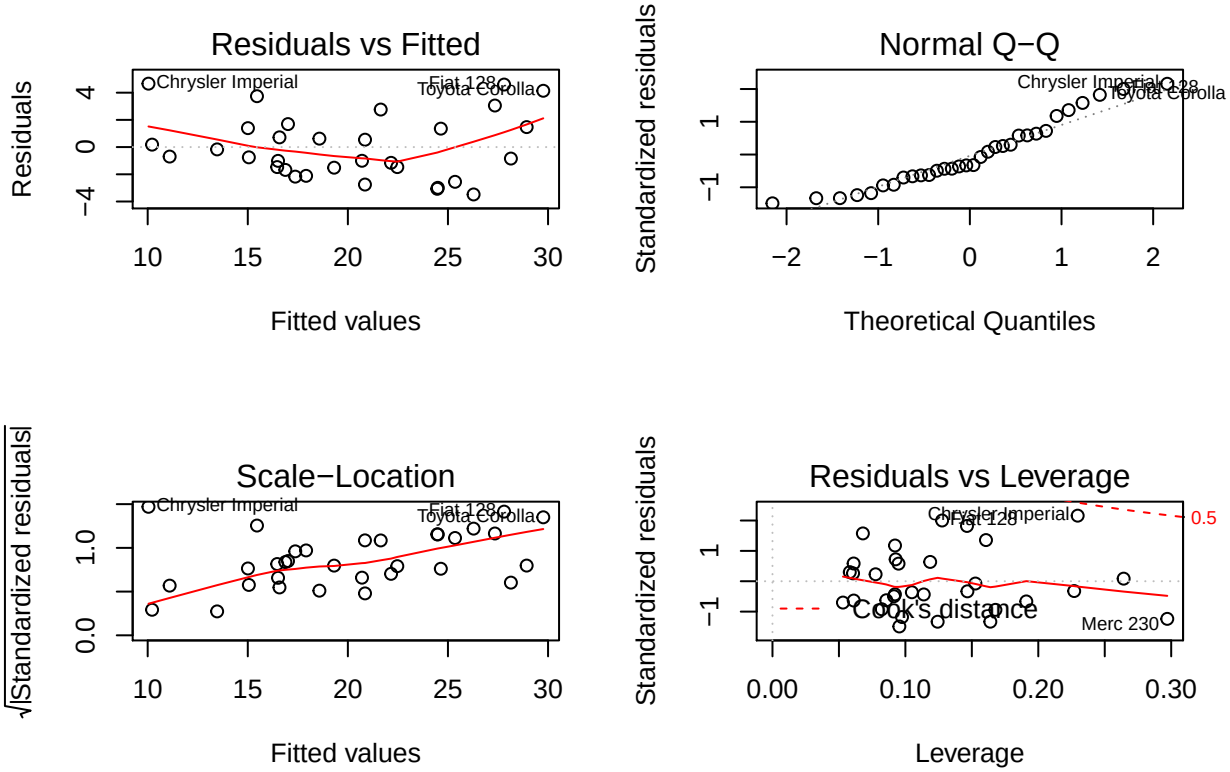
ANOVA Results of Step Process

```
sfit1$anova
```

```
##     Step Df    Deviance Resid. Df Resid. Dev      AIC
## 1        NA          NA        21   135.1573 68.10251
## 2 - drat  1  0.02529014        22   135.1826 66.10850
## 3   - vs  1  4.25043766        23   139.4330 65.09916
## 4 - carb  1  2.89754287        24   142.3306 63.75733
## 5 - disp  1  1.65114072        25   143.9817 62.12642
## 6  - cyl  2 16.08472969        27   160.0665 61.51530
## 7   - hp  1  9.21946935        28   169.2859 61.30730
```

Diagnostic Plots of Best Model

```
par(mfrow=c(2,2))
plot(sfit1)
```


Residuals vs Fitted
Residuals
Fitted values
Chrysler Imperial
Fiat 128
Toyota Corolla
Normal Q−Q
Standardized residuals
Theoretical Quantiles
Scale−Location
√|Standardized residuals|
Residuals vs Leverage
Cook's distance
0.5
Merc 230
Leverage