Analysis of variables affecting a car's fuel efficiency

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Executive Summary

I work for Motor Trend, a magazine about the automobile industry. I analyzed the mtcars car data to answer the following two questions:

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

For the data analyzed, a car with a manual tranmission is likely to have a higher fuel efficiency (MPG) than a car with an automatic transmission. Using a liner regression, the transmission type did have a statistically significant increase (2.9358) in MPG but is confounded by other variables. As the data did not include any cars that were identical except for the transmission type, further analysis may be needed.

Methodology

Source Data

The source data is mtcars in the R datasets library. The data was extracted from the 1974 Motor Trend US magazine, and comprises fuel consumption and 10 aspects of automobile design and performance for 32 automobiles (1973–74 models).[Ref1,FigureSet1]

Data Manipulation

I converted the variables vs and am as factors and I relabled the am factors to Autmoatic and Manual to improve understanding the visuals. I did not convert the variables gear, cyl, or carb as factors as the variables are not dichotomous or ordinal. For example increasing the number of gears has enabled better engineering optimization of a car's fuel efficiency[Ref2].

Data Exploration

In exploring the data I concluded that it is reasonable to consider MPG approximately normally distributed. the distribtuion for cars with an automatic tranmission appears normally distributed with a long tail to the right. The distribution for cars with a manual transmission are almost bimodal and are shifted to the right compared to cars with an automatic transmission. I noted that there are outliers at the right tail due to some cars with manual transmission having high MPG.[FigureSet2]

t.test of MPG ~ AM

The mean mileage of cars with an automatic transmission is 17 mpg and for cars with a manual transmission is 23 mpg. Treating the MPG data as i.i.d. and normally distributed, by t.test comparing MPG to the transmission type, the 95% confidence interval of the difference in mean gas mileage is between 3.21 and 11.28 mpg. As the mean does not include 0 and the p.value 0.0014 is less than an alpha level of 0.05, the difference is statistically significant.

Model Selection for linear regerssion

I used stepAIC for the model selection. The best regression model was (mpg ~ wt + qsec + am) which did find transmission type to be statistically significant with qsec and weight being statistically significant confounders (at an alpha of 0.05). I believe that additional modeling approaches should be employed.[Ref3]

Interpreting the linear model[FigureSet3]

The plot of residuals vs fitted indicate that residuals are uncorrelated and therefore are homoscedastic with normally distributed errors. However the scale-location plot indicates that the residuals might be heteroscedastic which would require tuning of the model such as by centering & scaling variables, testing for the interaction between variables, and possibly using different variables. None of the residuals had high leverage. The Q-Q plot shows that the data is approximately normally distributed except at the right tail as previouly shown in the data exploration.[FigureSet2]

References

1. mtcars dataset
2. Gear article
3. fivethirtyeight
4. QQNorm
5. Shapiro-Wilk normality test
6. r-tutur.com
7. Variances explained
8. Histogram Blog
9. Articles on interpreting lm: LM1 LM2 LM3 LM4

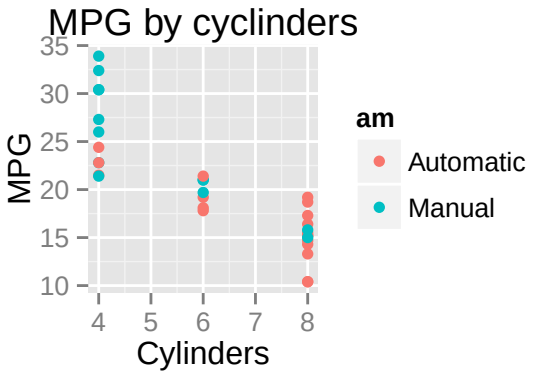
Appendix

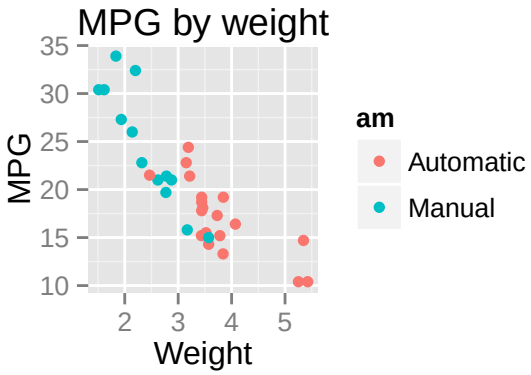
Figure set 1: basic data exploration

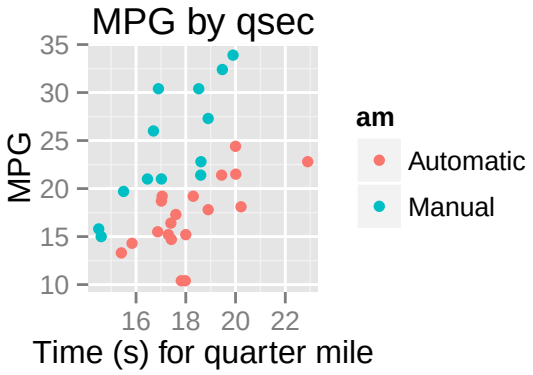
```
##       mpg             cyl             disp             hp       
##  Min.   :10.40   Min.   :4.000   Min.   : 71.1   Min.   : 52.0  
##  1st Qu.:15.43   1st Qu.:4.000   1st Qu.:120.8   1st Qu.: 96.5  
##  Median :19.20   Median :6.000   Median :196.3   Median :123.0  
##  Mean   :20.09   Mean   :6.188   Mean   :230.7   Mean   :146.7  
##  3rd Qu.:22.80   3rd Qu.:8.000   3rd Qu.:326.0   3rd Qu.:180.0  
##  Max.   :33.90   Max.   :8.000   Max.   :472.0   Max.   :335.0  
##       drat             wt             qsec       vs             am         
##  Min.   :2.760   Min.   :1.513   Min.   :14.50   0:18   Automatic:19  
##  1st Qu.:3.080   1st Qu.:2.581   1st Qu.:16.89   1:14   Manual   :13  
##  Median :3.695   Median :3.325   Median :17.71                        
##  Mean   :3.597   Mean   :3.217   Mean   :17.85                        
##  3rd Qu.:3.920   3rd Qu.:3.610   3rd Qu.:18.90                        
##  Max.   :4.930   Max.   :5.424   Max.   :22.90                        
##       gear            carb      
##  Min.   :3.000   Min.   :1.000  
##  1st Qu.:3.000   1st Qu.:2.000  
##  Median :4.000   Median :2.000
```

```
##  Mean   :3.688   Mean   :2.812
##  3rd Qu.:4.000   3rd Qu.:4.000
##  Max.   :5.000   Max.   :8.000
```

```
## '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  : Factor w/ 2 levels "0","1": 1 1 2 2 1 2 1 2 2 2 ...
##  $ am  : Factor w/ 2 levels "Automatic","Manual": 2 2 2 1 1 1 1 1 1 1 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```







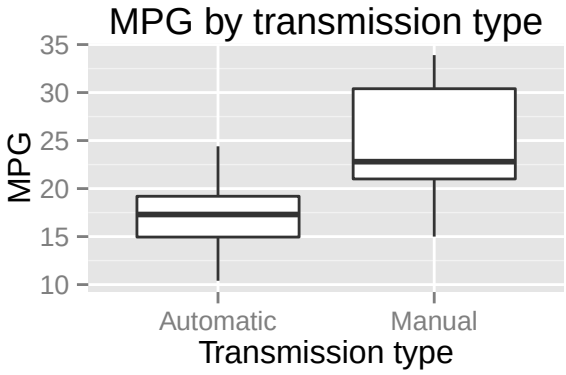


Figure set 2: MPG distribution

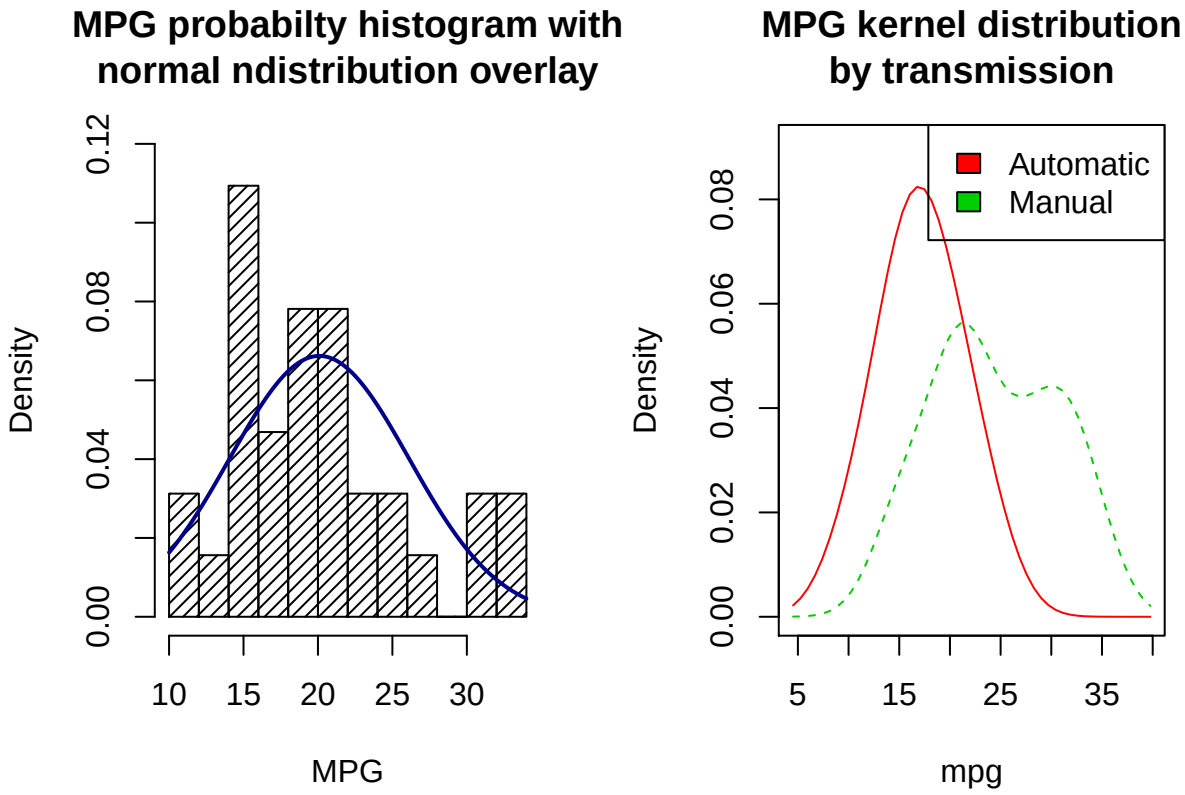
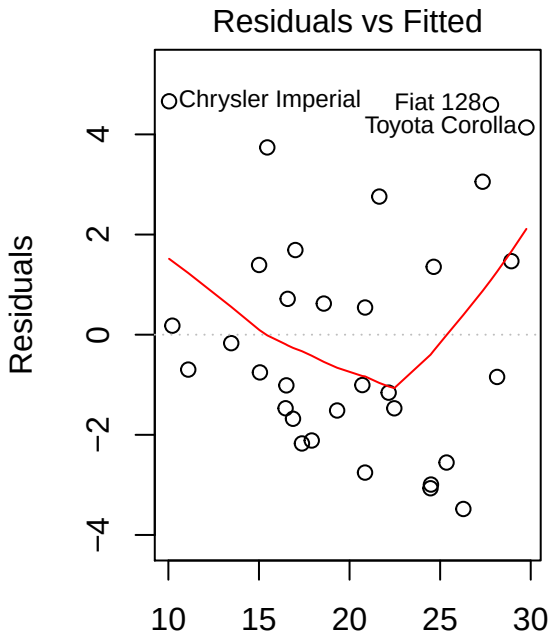
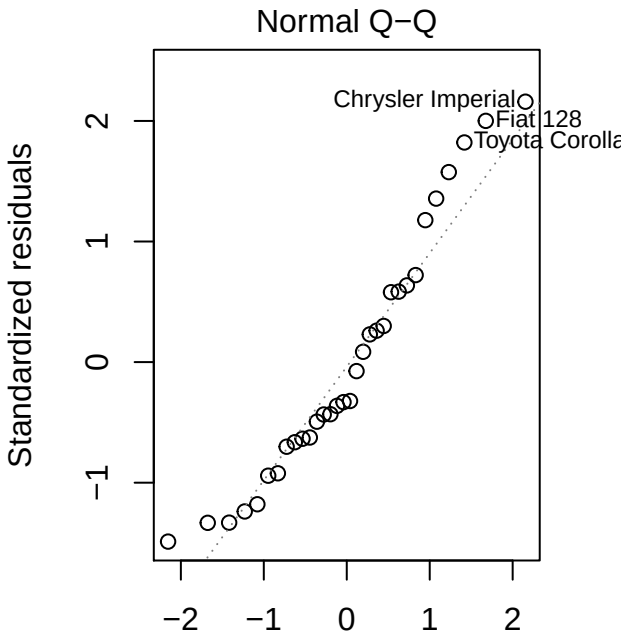
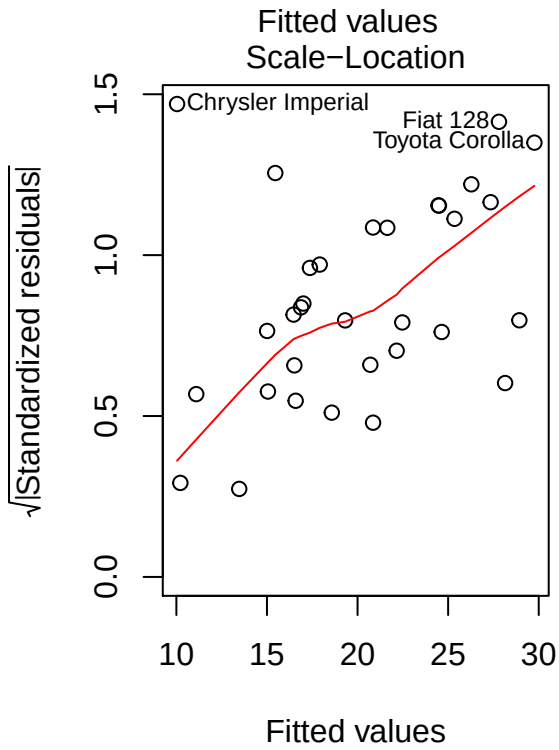


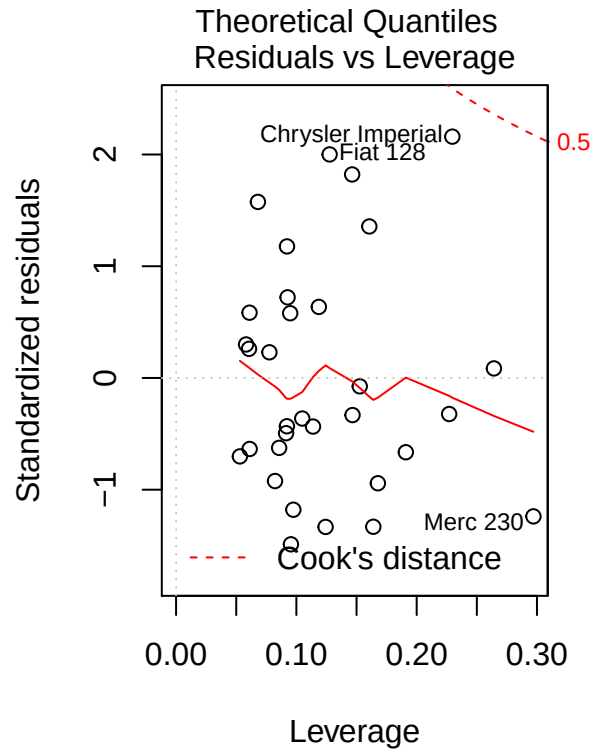
Figure set 3: stepAIC

```
##
## Call:
## lm(formula = mpg ~ wt + qsec + am, data = M1)
##
## 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
```


Residuals vs Fitted
Chrysler Imperial
Fiat 128
Toyota Corolla
Residuals
10
15
20
25
30
−4
−2
0
2
4


Normal Q−Q
Chrysler Imperial
Fiat 128
Toyota Corolla
Standardized residuals
−2
−1
0
1
2


Scale−Location
Chrysler Imperial
Fiat 128
Toyota Corolla
√|Standardized residuals|
Fitted values
10
15
20
25
30
0.0
0.5
1.0
1.5


Residuals vs Leverage
Chrysler Imperial
Fiat 128
Merc 230
0.5
Cook's distance
Standardized residuals
Leverage
0.00
0.10
0.20
0.30
−1
0
1
2