Regression Analysis on Motor Trend Dataset

freestander

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Executive Summary

Motor Trend is interested in exploring the relationship between a set of variables and miles per gallon (MPG) (outcome) by looking at a data set of a collection of cars. In this analysis, we are trying 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"

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).

Exploratory Data Analysis

First, we review each field in the dataset using the summary function and also draw a pariwise scattor plot between the variables (shown in appendix).

```
summary(mtcars)
```

```
##       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
##  Min.   :2.760   Min.   :1.513   Min.   :14.50   Min.   :0.0000
##  1st Qu.:3.080   1st Qu.:2.581   1st Qu.:16.89   1st Qu.:0.0000
##  Median :3.695   Median :3.325   Median :17.71   Median :0.0000
##  Mean   :3.597   Mean   :3.217   Mean   :17.85   Mean   :0.4375
##  3rd Qu.:3.920   3rd Qu.:3.610   3rd Qu.:18.90   3rd Qu.:1.0000
##  Max.   :4.930   Max.   :5.424   Max.   :22.90   Max.   :1.0000
##        am              gear            carb
##  Min.   :0.0000   Min.   :3.000   Min.   :1.000
##  1st Qu.:0.0000   1st Qu.:3.000   1st Qu.:2.000
##  Median :0.0000   Median :4.000   Median :2.000
##  Mean   :0.4062   Mean   :3.688   Mean   :2.812
##  3rd Qu.:1.0000   3rd Qu.:4.000   3rd Qu.:4.000
##  Max.   :1.0000   Max.   :5.000   Max.   :8.000
```

Data Preprocessing

Next, we transform some categorical variables into factor types to prepare for the regression analysis in the later steps.

```r
mtcars$cyl <- factor(mtcars$cyl)
mtcars$vs <- factor(mtcars$vs)
mtcars$am <- factor(mtcars$am, labels=c('Automatic','Manual'))
mtcars$gear <- factor(mtcars$gear)
mtcars$carb <- factor(mtcars$carb)
```

Comparison of Automatic vs Manual Transmission in MPG

We draw a boxplot of MPG for different transmission types (show in appendix). By visual inpsection it looks like the manual transmission is better than the automatic transmission in MPG. We further conduct a t-test to confirm this.

```r
t.test(mpg ~ am, data = mtcars)
```

```
##
##  Welch Two Sample t-test
##
## data:  mpg by am
## t = -3.7671, df = 18.332, p-value = 0.001374
## alternative hypothesis: true difference in means is not equal to 0
## 95 percent confidence interval:
##  -11.280194  -3.209684
## sample estimates:
## mean in group Automatic    mean in group Manual
##                17.14737                24.39231
```

Since the p-value is 0.00137, and the lower and upper bounds of 95% confidence interval are both below 0. The mean in group Automatic is 17.14737 and the mean in group Manual is 24.39231. Thus we reject our null hypothesis and conclude the manual transmission is better than the automatic transmission in MPG.

Regression Model Selection

We use regression model to identify the variables that account for MPG differences.

First we try the single vairable regression model where there is only one variable "am". The p-value is 0.000285, and the adjusted R-squared is only 0.3385, which means the model only accounts for 33.85% variance.

```r
m1 <- lm(mpg ~ am, data = mtcars)
summary(m1)
```

```
##
## Call:
## lm(formula = mpg ~ am, data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -9.3923 -3.0923 -0.2974  3.2439  9.5077
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)   17.147      1.125  15.247 1.13e-15 ***
## amManual       7.245      1.764   4.106 0.000285 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.902 on 30 degrees of freedom
## Multiple R-squared:  0.3598, Adjusted R-squared:  0.3385
## F-statistic: 16.86 on 1 and 30 DF,  p-value: 0.000285
```

Next, we try the multivariate linear regression with all variables included. The p-value is 0.000124, and the adjusted R-squared is 0.779, which means the model accounts for 77.9% variance. Although there is a great improvement in adjusted R-squared, it doesn't mean all variables should be included. From the coefficients below, we can see some of the variables have insignificant p-value thus may bring noise to the model if included in the regression.

```
m2 <- lm(mpg ~ ., data = mtcars)
summary(m2)
```

```
##
## Call:
## lm(formula = mpg ~ ., data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.5087 -1.3584 -0.0948  0.7745  4.6251
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 23.87913   20.06582   1.190   0.2525
## cyl6        -2.64870    3.04089  -0.871   0.3975
## cyl8        -0.33616    7.15954  -0.047   0.9632
## disp         0.03555    0.03190   1.114   0.2827
## hp          -0.07051    0.03943  -1.788   0.0939 .
## drat         1.18283    2.48348   0.476   0.6407
## wt          -4.52978    2.53875  -1.784   0.0946 .
## qsec         0.36784    0.93540   0.393   0.6997
## vs1          1.93085    2.87126   0.672   0.5115
## amManual     1.21212    3.21355   0.377   0.7113
## gear4        1.11435    3.79952   0.293   0.7733
## gear5        2.52840    3.73636   0.677   0.5089
## carb2       -0.97935    2.31797  -0.423   0.6787
## carb3        2.99964    4.29355   0.699   0.4955
## carb4        1.09142    4.44962   0.245   0.8096
## carb6        4.47757    6.38406   0.701   0.4938
## carb8        7.25041    8.36057   0.867   0.3995
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.833 on 15 degrees of freedom
## Multiple R-squared:  0.8931, Adjusted R-squared:  0.779
## F-statistic:  7.83 on 16 and 15 DF,  p-value: 0.000124
```

In the final step, we perform a stepwise model selection using backward elimination.

```
m3 <- step(m2, direction="backward")
```

The remaining variables ("cyl", "hp", "wt", "am") are significant and fit the model best. The p-value is 1.506e-10, and the adjusted R-squared is 0.8401, which means the model accounts for 84.01% variance. Compared to automatic transmission, MPG increases by 1.8 if having a manual transmission. Moreover, the regression result shows MPG decreases -3.03 for "cyl6", -2.16 for "cyl8", -0.03 for "hp", -2.5 for "wt", respectively.

```
summary(m3)
```

```
##
## Call:
## lm(formula = mpg ~ cyl + hp + wt + am, data = mtcars)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -3.9387 -1.2560 -0.4013  1.1253  5.0513
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 33.70832    2.60489  12.940 7.73e-13 ***
## cyl6        -3.03134    1.40728  -2.154  0.04068 *
## cyl8        -2.16368    2.28425  -0.947  0.35225
## hp          -0.03211    0.01369  -2.345  0.02693 *
## wt          -2.49683    0.88559  -2.819  0.00908 **
## amManual     1.80921    1.39630   1.296  0.20646
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.41 on 26 degrees of freedom
## Multiple R-squared:  0.8659, Adjusted R-squared:  0.8401
## F-statistic: 33.57 on 5 and 26 DF,  p-value: 1.506e-10
```

We also do the residual plots (shown in appendix) to check how well the regression model fits. The "Residuals vs Fitted" plot shows no pattern, supporting the independence assumption. The "Normal Q-Q" plot shows that residuals can be approximated by normal distribution. The "Scale-Location" plot shows that the points are randomly distributed, supporting constant variance assumption. The "Residuals vs Leverage" plot shows that no particular outlier is observed.

Conclusion

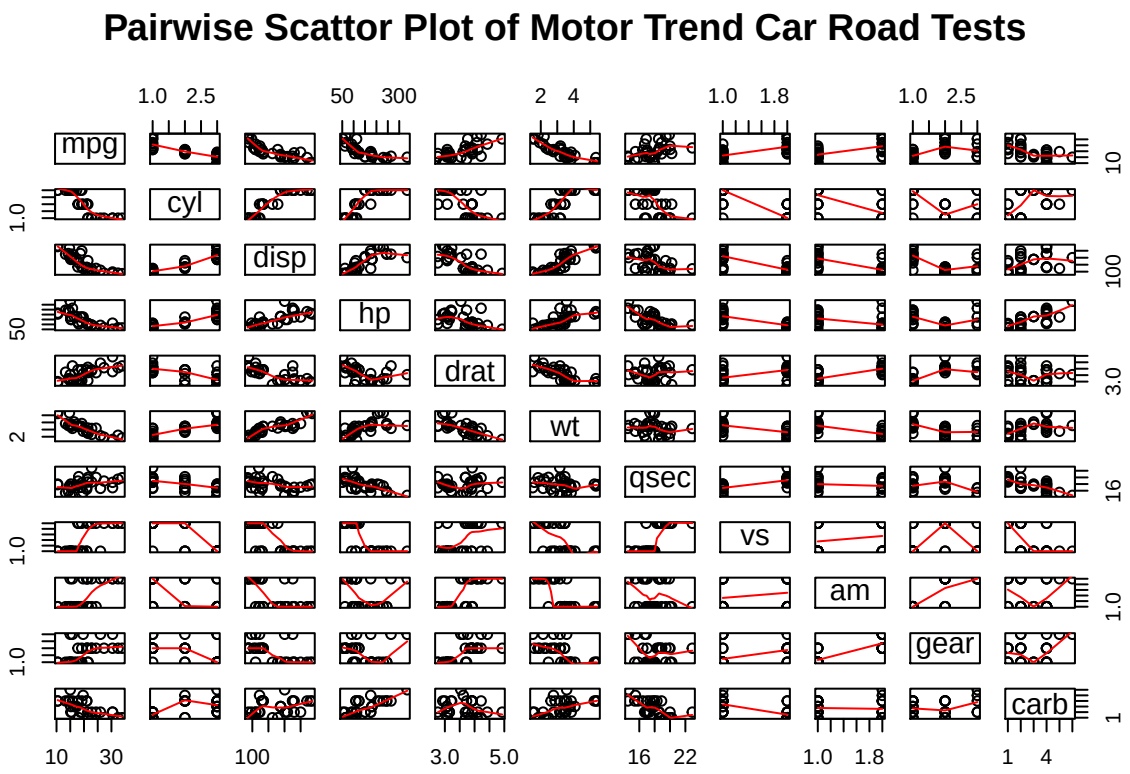
According to the t-test with 95% condifence interval, manual tranmission has higher MPG than automatic transmission. The mean in group Automatic is 17.14737 and the mean in group Manual is 24.39231. From the best regression model, we can see that rate of change in MPG with respect to manual transmission compared to automatic transmission is about 1.8.

However, there are some limitations that we need to address to further improve the analysis result. For example, the residual plots show some transformation of the variables are needed to achieve linearity, and the sample size is too small (only 32 records) to arrive at a reliable conclusion.

Appendix

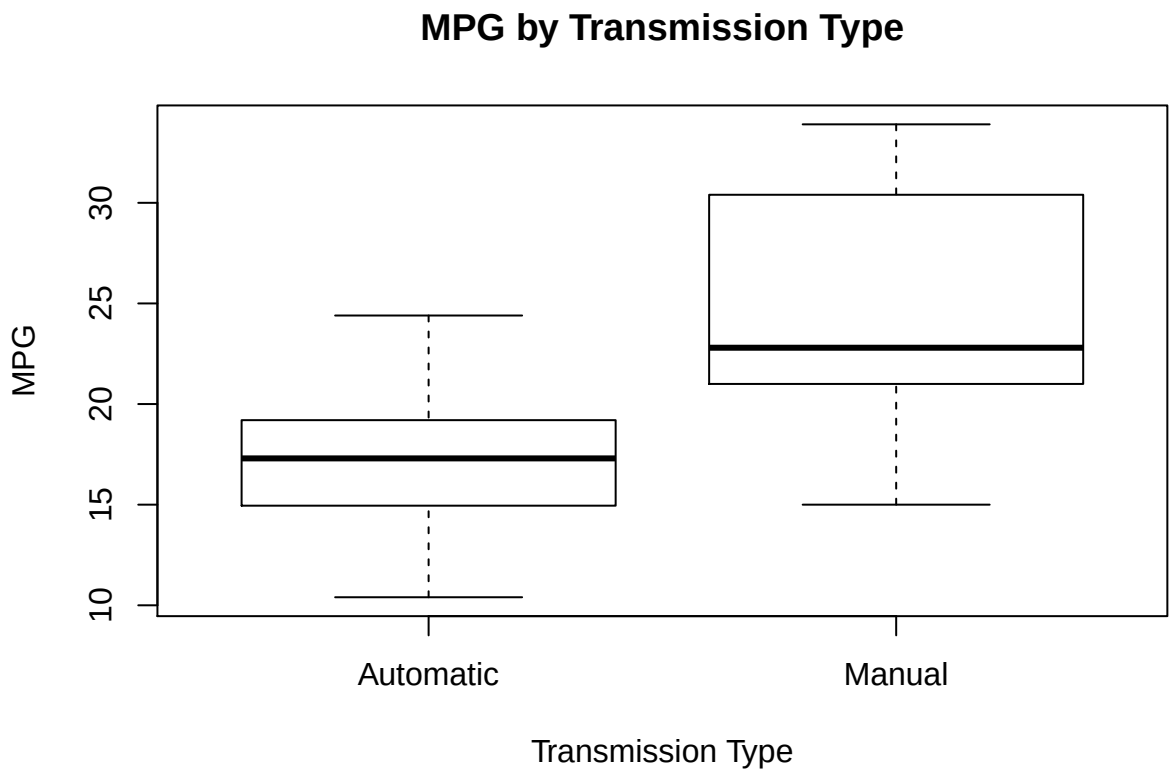
The following is a pairwise scattor plot between different variables.

```
pairs(mtcars, panel=panel.smooth, main="Pairwise Scattor Plot of Motor Trend Car Road Tests")
```



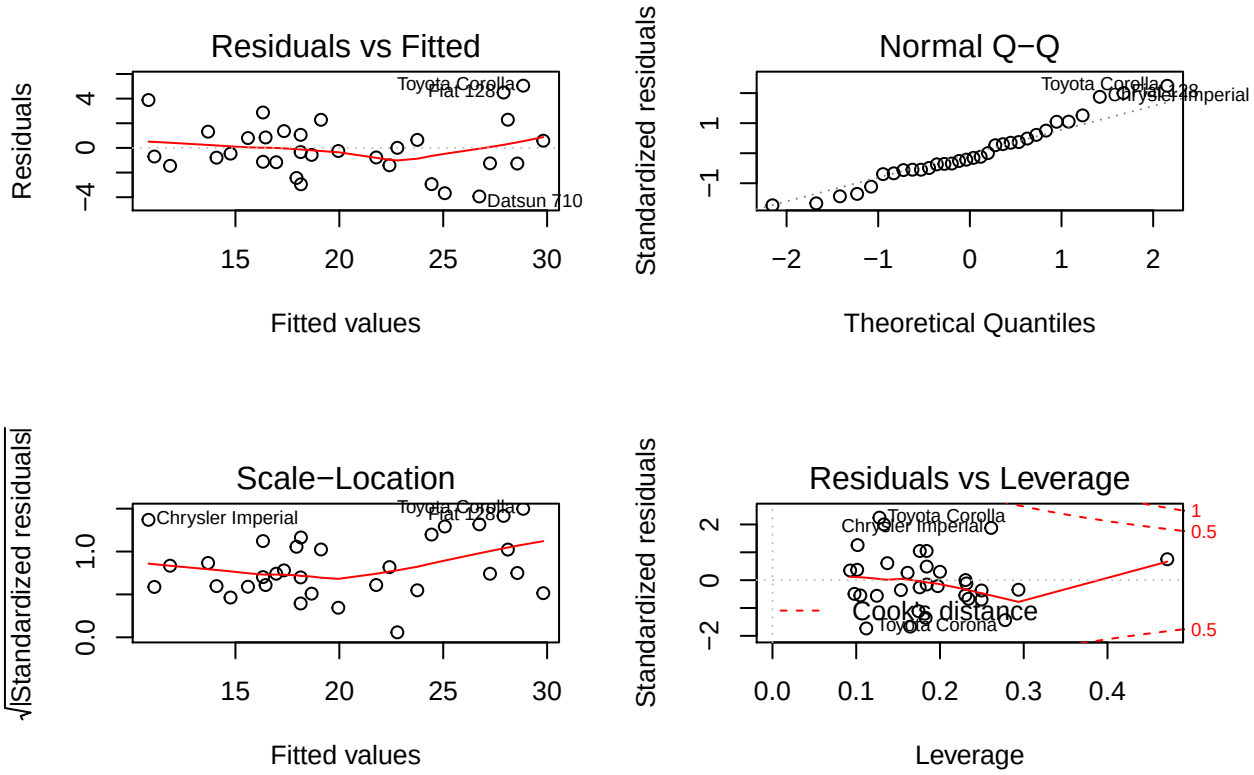
The following is a boxplot of MPG for different transmission types.

```
boxplot(mpg ~ am, data = mtcars, xlab = "Transmission Type", ylab = "MPG", main="MPG by Transmission Ty
```



The following are the residual plots to check how well the regression model fits.

```
par(mfrow = c(2, 2))
plot(m3)
```


Residuals vs Fitted
Residuals
Fitted values
Toyota Corolla
Fiat 128
Datsun 710
Normal Q−Q
Standardized residuals
Theoretical Quantiles
Toyota Corolla
Chrysler Imperial
Scale−Location
√|Standardized residuals|
Fitted values
Chrysler Imperial
Toyota Corolla
Fiat 128
Residuals vs Leverage
Standardized residuals
Leverage
Cook's distance
Toyota Corolla
Chrysler Imperial
Toyota Corona