

# Peer graded assignment regression models

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## Executive Summary

This study is conducted to explore the relationship between a set of variables and the fuel consumption. The focus of is to address two questions.

“Is an automatic or manual transmission better for MPG”

“Quantify the MPG difference between automatic and manual transmissions”

By perform variable F-test and one way ANOVA test, evidences are observed support relationship between transmission type and fule economy. With multi-variable linear regression model, the conclusion is manula transmission results higher MPG number by 2.94 mile per gallon compares to automatic transmission, this result has 1.41 mpg standard error.

## Data Exploration

We will use “mtcars” data to draw conclusions, mtcars is a 32 by 11 data frame, see **table 1** for the description of each column. Each column also been given the *possible* effect to MPG with hifger value,

Table 1, data columns decription and categories

```
kable(mtcars.tab)
```

column.name	defination	effect.on.higher.value	variable.category
mpg	miles per gallon(US)		outcome
cyl	number of cylinders	high power output	engine specs
disp	engine displacement(cu. in.)	high power output	engine specs
hp	Gross horsepower	high fuel consumption	drivetrain specs
drat	Rear axle ratio	faster acceleration	drivetrain specs
wt	Weight (1000 lbs)	slower acceleration	vehicle specs
qsec	zero to 1/4 mile time in seconds	slower acceleration	performance measurement
vs	Engine shape (0 = V-shaped, 1 = straight)	factor	drivetrain specs
am	Transmission (0 = automatic, 1 = manual)	factor	drivetrain specs
gear	Number of forward gears	faster acceleration	drivetrain specs
carb	Number of carburetors	high power output	engine specs

Figure 1 in appendix shows the correlation between all variables

## Relatinoship between MPG and AM

### Correlation

From figure 1, we can see the MPG and AM variables has 0.5998 correlation value, it a indication MPG and AM has relationship, but not strong enough. Therefore, to answer first question, we need better evidences.

We will test the correlation between MPG and AM with alternative hypothesis “true correlation is greater than zero”

```
cor.test(mpg, am, alternative = "greater")

##
## Pearson's product-moment correlation
##
## data: mpg and am
## t = 4.1061, df = 30, p-value = 0.0001425
## alternative hypothesis: true correlation is greater than 0
## 95 percent confidence interval:
##  0.3691544 1.0000000
## sample estimates:
##      cor
## 0.5998324
```

From the output, p-value is far away from 95% confidence interval, this is a good evidence *supporting*  $H_a$ , which is MPG and AM are correlated.

## One way ANOVA

To further prove the opposite is false, we can use one-way ANOVA. The null hypothesis of the analysis is **the mean MPG are the same between samples**.

```
anova1 <- aov(mpg ~ am, data = mtcars)
summary(anova1)

##           Df Sum Sq Mean Sq F value    Pr(>F)
## am           1  405.2   405.2    16.86 0.000285 ***
## Residuals    30   720.9    24.0
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

f_crit <- round(qf(0.95, 1, 30), 2)
```

F value of 16.86 is significantly larger than the 95% confidence interval critical value 4.17, the result shows strong evident *rejecting* null hypothesis.

## Regression

### simple regression

For the sake of comparison, let's do a single variable(factor actually) linear model.

```
mod.sim <- lm(mpg ~ am, data = mtcars)
summary(mod.sim)

##
## 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 ***
## am              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
```

To interpret the output, the coefficient of AM is 7.245, which means changing from auto to manual, will result on average 7.245 mile/gallon fuel consumption increase. However, as expected, the model quality is

low, we can't use it to predict the MPG, when only around 36% of residuals variance are explained by this model, AM is a dummy variable after all.

## selection of independent variables

To make a multi-variable linear regression model, there are ten variables to choose from. we need to avoid choose highly correlated variables, take a quick look at first summary plot, we can see quite some variables are highly related.

This is not a big surprise, with basic car knowledge we can understand why some of independent variables are correlated. For example, more cycles of an engine normally means bigger displacement, higher the horsepower normally results lower quarter mile time.

We can categorize those ten variables into following group

- 1, drivetrain specifications: cyl, disp, drat, vs, carb, drat, am, gear
- 2, other vehicle specifications: wt
- 3, performance measurements: qsec, hp

we can choose ourselves and compare the results but better option is to get help from package "leaps".

Here we did an exhausted subset comparison, with one best result from each number of variable combination. from the right plot, we can see the adjusted R square does not show big difference after 0.7, the Mallows' Cp however have one very low value compares to other combinations. Therefore, we will create regression model with independent variables of weight, quarter mile time, and auto/manual transmission.

```
mod.m1 <- lm(mpg ~ wt + qsec + am, data = mtcars)
summary(mod.m1)

##
## 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 ***
## am            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
```

Interpretation of the output: This model tells us on every 1000 pounds increase, the vehicle fuel economy will reduce by 3.9165 mpg if other two variables remain unchanged. This is expected as the heavier the car, the worse the fuel economy.

The next line quarter mile seconds read as every second increase for a car from stand to reach quarter mile, the fuel economy will increase 1.2259 mpg, if other variable remain unchanged. The explanation is the lower "qsec" the faster car can travel, normally this is result of more powerful engine, which yields worse mpg number.

Next line of am is the answer to second question, if other variables are unchanged, we only change transmission from auto to manual, it will improve car fuel economy by 2.9358 mpg.

Now we examine the significant level of each of those variables. Both weight and quarter mile seconds are highly significant to fuel economy, with very small p-value. However the "am" is just below 95% critical value, this tells us transmission type is related to MPG but not as significant as other two variables.

## Regression Residuals

Finally we want to check the residual plot and distribution, to verify if

- 1, distribution is fairly normal.
- 2, if multi-variable regression residual has smaller variation.

## Appendix

Figure 1, variable correlation grid

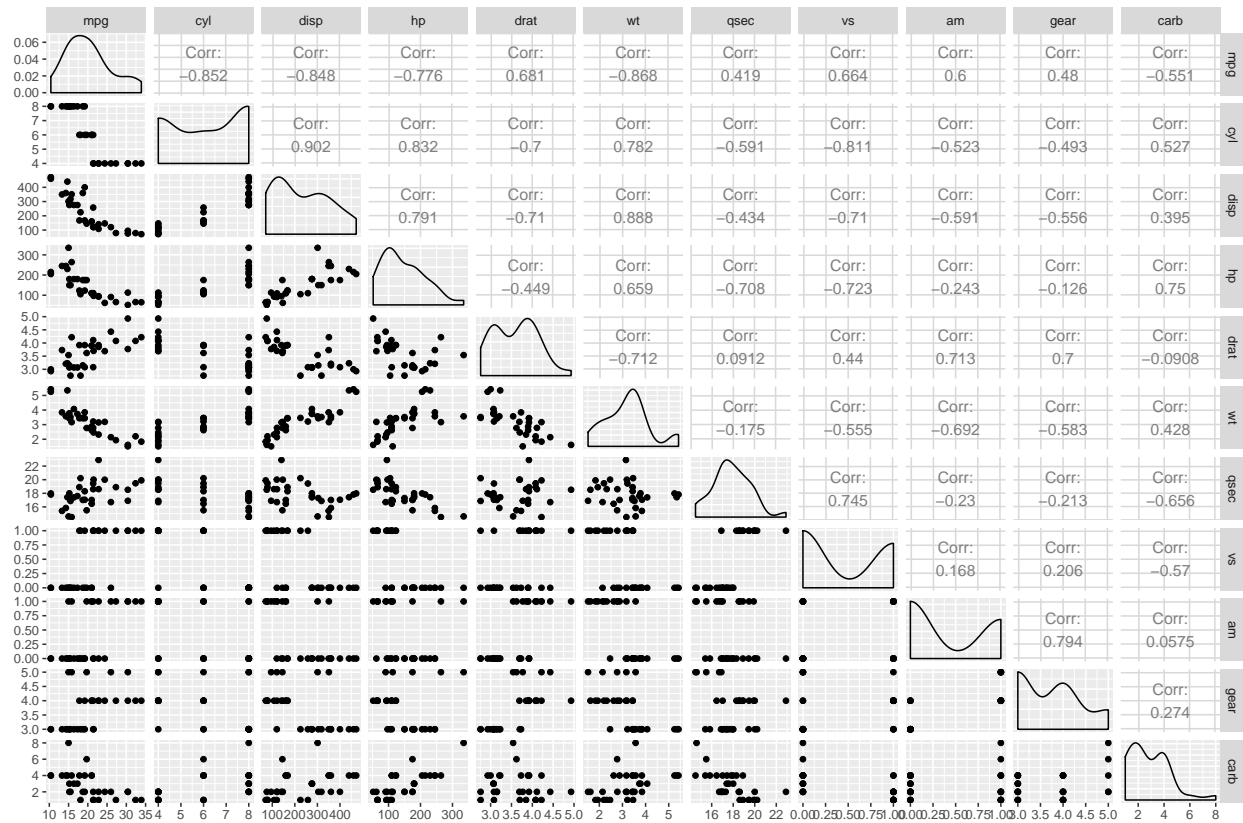
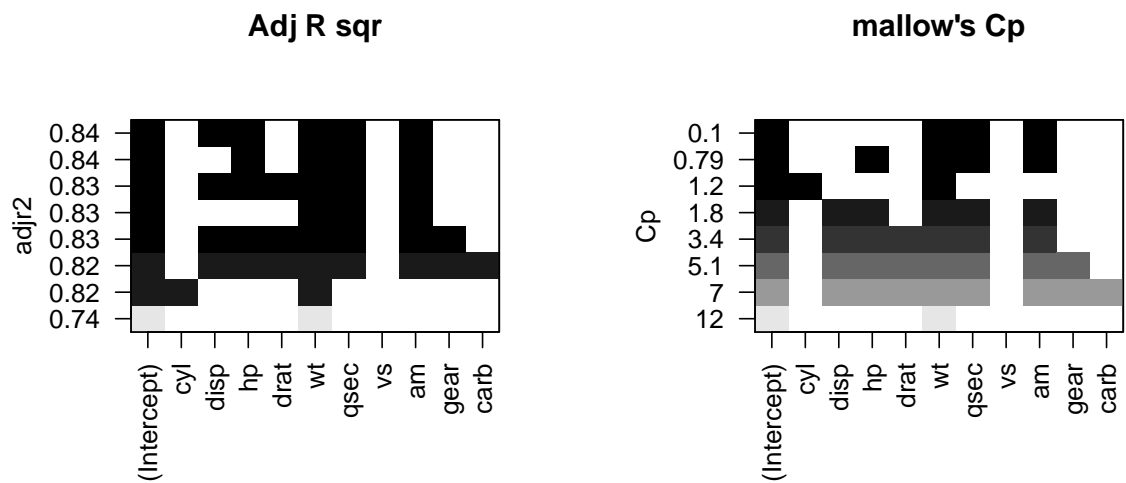


Figure 2, regression subset selection



### Figure 3, Multi-variable regression model

finger 3, MPG with auto(blue) and manual(red)

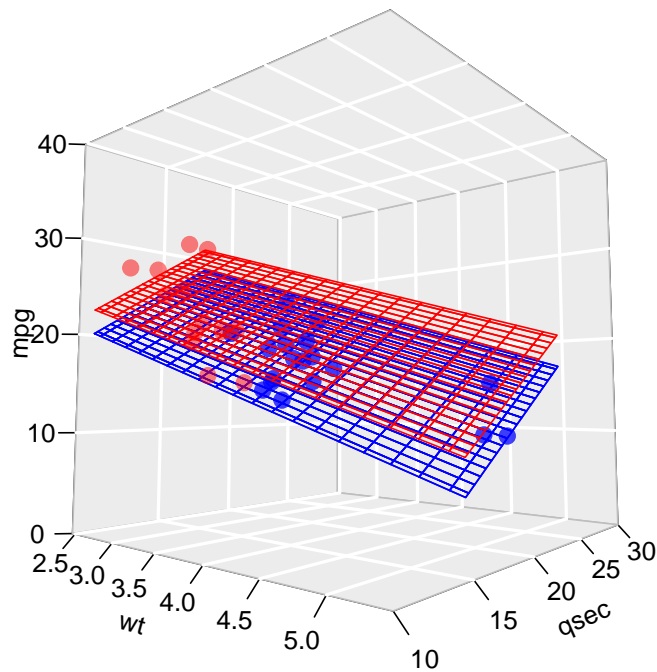


Figure 4, regression residuals

