Regression Models Course Project

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Executive Summary

In this project, analysis of the `mtcars` data set is done; and the relationship between some variables and the Miles per Gallon (MPG) of cars is explored and analyzed. The main questions that are solved in this project are: *Is an automatic or manual transmission better for MPG ?*, and *Quantify the MPG difference between automatic and manual transmission.* Various regression models and exploratory data analyses are used to analyze how having automatic or manual transmission in a car effects its MPG rating. To check whether automatic or manual transmission is better for performance, several regression models are fitted on the data set with MPG as outcome, and the one with highest adjusted R-squared value is selected (this high value is obtained by using other variables in the model fit alongside the automatic transmission variable). From the best fit model, considering 1/4 mile time and weight of the car to be constants, the MPG of manual transmission cars is `14.08+(-4.14)*weight` more on average than automatic transmission cars. Performing T-tests between the mpg of cars with manual transmission and automatic transmission suggests that there is a significant difference between the MPG of cars with manual transmission and the MPG of cars with automatic transmission. From the t-test, it is evident that the MPG of manual transmission cars are approximately 7 more than that of automatic transmission cars.

Question 1

1. Exploratory Data Analysis

Some of the variables in the data set that have multiple values of the same type are converted into factor variables

```
# loading the mtcars data set
data("mtcars")

# converting some variables into factor variables
mtcars$am <- as.factor(mtcars$am)
mtcars$vs <- as.factor(mtcars$vs)
mtcars$gear <- as.factor(mtcars$gear)
mtcars$cyl <- as.factor(mtcars$cyl)
mtcars$carb <- as.factor(mtcars$carb)
```

A box-plot is created showing the difference between the `mpg` of the cars with manual transmission and automatic transmission (can be found in *appendix*)

2. Regression Modeling

A linear regression model with `mpg` as outcome and the other variables as the predictors is created, just as a starting point to see how to proceed.

```
# output of code is suppressed
baseModel <- lm(mpg ~ ., data = mtcars)
summary(baseModel)
```

From the model, the adjusted R-squared value is 78%, which means that the model can explain 78% of the variance in the `mpg` variable. Also, all of the coefficients in the model have a significance level (p-value) of more than 0.05, which means that none of the coefficients are significant in the model. The residual standard error for this model is 2.833 with 15 degrees of freedom.

To select the most statistically significant variables, backward selection method is used.

```
# output of code is suppressed
backModel <- step(baseModel, k = log(nrow(mtcars)))
summary(backModel)
```

From the backward selection model, the selected variables are `am`, `qsec` and `wt`, wherein `am` is factor variable with `0` denoting automatic and `1` denoting manual transmission, `qsec` is 1/4 mile time, and `wt` is the car weight in 1000 lbs. The adjusted R-squared is 0.8497, which is more than the previous model. All the variables are significant, with a significance level below 0.05. The residual standard error for this model is 2.46 with 28 degrees of freedom.

In the scatter plot comparing `mpg` vs `wt` with `am` used to color the dots (see in the *appendix*), it is evident that there is some interaction between `wt` and `am`, wherein automatic transmission cars seem to have more weight than manual transmission cars. So, an interaction term can be added to the above model.

```
# output of code is suppressed
backModelInt <- lm(mpg ~ wt + qsec + am + wt:am, data = mtcars)
summary(backModelInt)
```

The model has an adjusted R-squared of 0.8959, which is even more than the best model found from the backward selection method. Also, all of the coefficients have a significance level below 0.05, which means that they are significant coefficients. The residual standard error for this model is 2.084 with 27 degrees of freedom (the lowest out of the three models).

The last model being fitted considers `mpg` as outcome and `am` as the predictor.

```
# output of code is suppressed
simModel <- lm(mpg ~ am, data = mtcars)
summary(simModel)
```

The adjusted R-squared for this model is 0.36, which is much lower than the other three models. The cars with automatic transmission has an average MPG of 17.147, and the average MPG for manual transmission cars is 7.245 more than the automatic. The residual standard error for this model is 4.902 with 30 degrees of freedom. Since the adjusted R-squared value is so low, other variables should be included in the model (as has been done in the previous three models).

The final model selected is the `backModelInt`, with `wt`, `qsec`, `am` and `wt:am` as the predictors.

```
#summary of the coefficients
summary(backModelInt)$coef
```

```
##              Estimate Std. Error   t value     Pr(>|t|)
## (Intercept)  9.723053  5.8990407  1.648243 0.1108925394
## wt          -2.936531  0.6660253 -4.409038 0.0001488947
## qsec         1.016974  0.2520152  4.035366 0.0004030165
## am1         14.079428  3.4352512  4.098515 0.0003408693
## wt:am1      -4.141376  1.1968119 -3.460340 0.0018085763
```

From the coefficients' summary, it is evident that the manual transmission cars are better than automatic transmission cars for MPG. Considered the `wt` and `qsec` variable constant, the MPG for manual transmission cars is `14.08+(-4.14)*weight` more on average than that of automatic transmission cars. Thus, the first question has been answered.

Question 2

1. Hypothesis Testing

```
tTest <- t.test(mpg ~ am, data = mtcars)
tTest
```

```
##
##  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 0 mean in group 1
##        17.14737        24.39231
```

Now, the difference in MPG between manual and automatic transmission cars has to be quantified. First, the distribution of MPG for manual and automatic cars will be explored via a box-plot (see in *appendix*). From the box-plot, we can see that the MPG for manual transmission is higher than that of automatic. This difference can be confirmed statistically via a two-sample, two-sided t-test. The MPG distribution is assumed to be approximately normal, and the manual and automatic transmission MPG values are assumed to be random samples from the same population (with constant variance). (see in *appendix*).

The difference in mean MPG between automatic and manual transmission has a confidence interval of -11.28 to -3.21. Also, the p-value is 0.001374, means that there is significant evidence to reject the null hypothesis, and there is a significant difference in mean MPG between automatic and manual transmission, at a significance level of 0.05. Also, in the sample collected, the mean MPG of manual transmission is approximately 7 more than that of automatic transmission. Hence, the second question is also answered.

Residual Plots and Diagnostics

The residual plots for the selected model in the first question have been created (see in *appendix*). The following assumptions are true from the plot:

- The residuals versus fitted values plot shows that there is no particular pattern in the residuals, which proves the assumption of independence.
- The residuals versus leverage plot shows that no outliers are present in the data, since all points lie within the 0.5 bands.
- The normal Q-Q plot proves the normality assumption of the data, because the quantiles from the data are similar to the normal quantiles.
- The scale-location plot proves the assumption of constant variance, since the points are distributed randomly.

The `dfbetas`, which is the measure of how much effect an observation has on the estimate of a regression coefficient, is shown below.

```
sum((abs(dfbetas(backModelInt)))>1)
```

```
## [1] 0
```

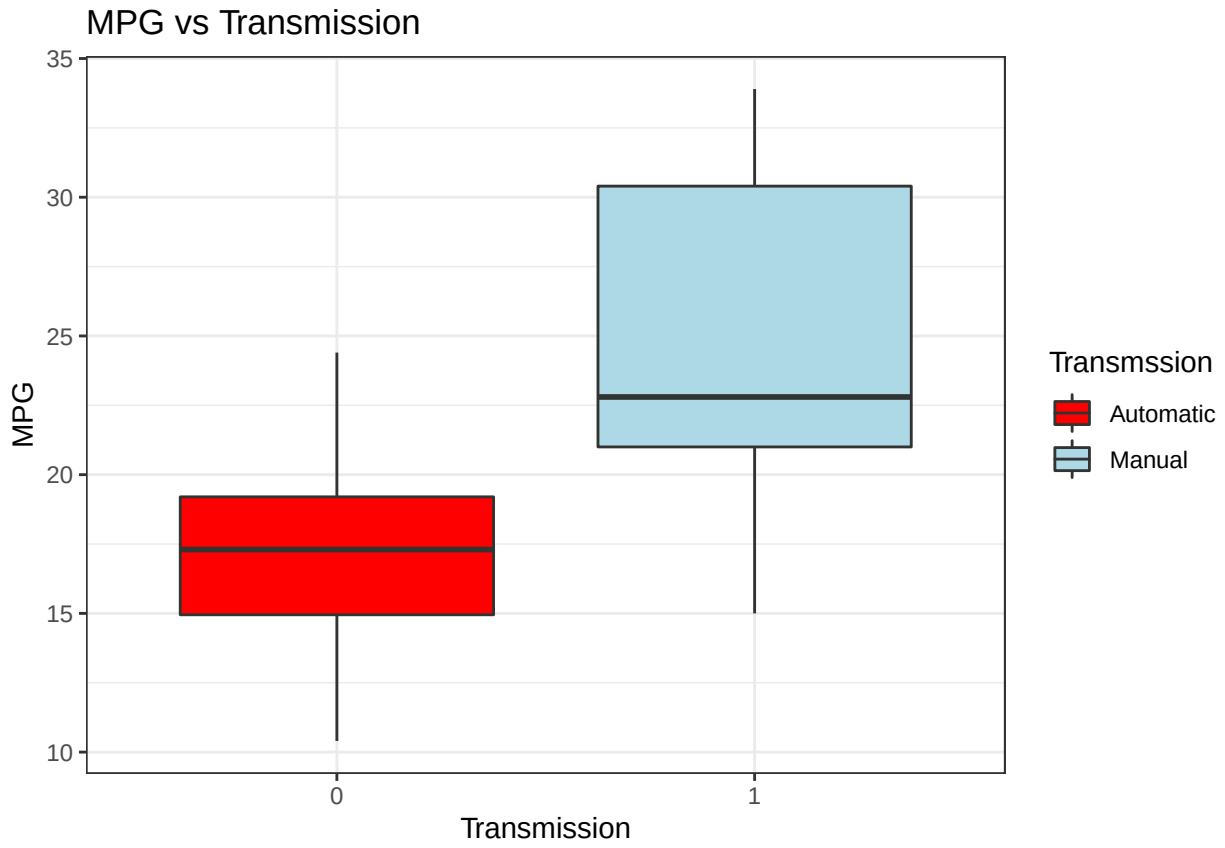
Thus, all the assumptions needed to perform linear regression are true.

Appendix

1. Boxplot of mpg vs am

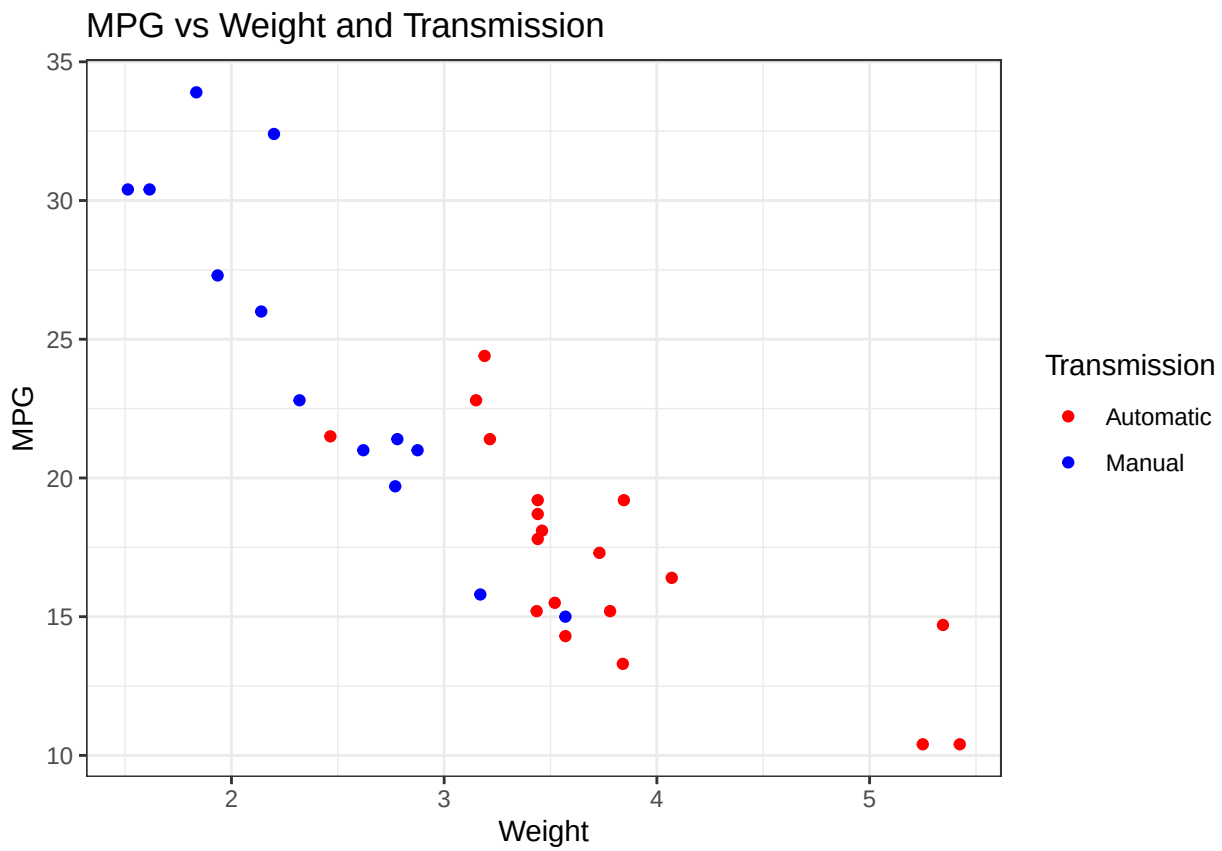
```
#loading the 'ggplot2' package
library(ggplot2)
```

```
ggplot(aes(x = am, y = mpg), data = mtcars) +
    geom_boxplot(aes(fill = am)) +
    labs(x = "Transmission", y = "MPG", title = "MPG vs Transmission",
         fill = "Transmssion") + theme_bw() +
    scale_fill_manual(labels = c("Automatic", "Manual"), values = c("red", "light blue"))
```



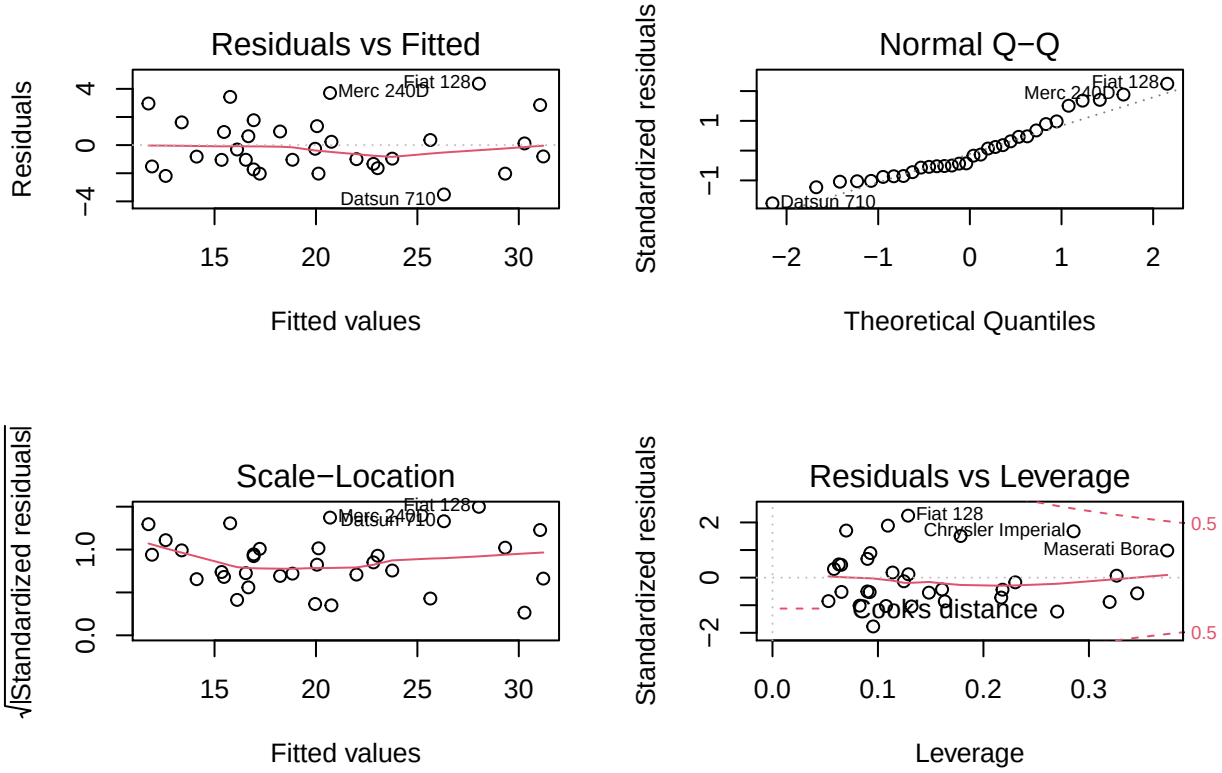
2. Scatter plot of mpg vs wt with points colored by am

```
ggplot(aes(x = wt, y = mpg, color = am), data = mtcars) +
    geom_point() + theme_bw() +
    labs(x = "Weight", y = "MPG", title = "MPG vs Weight and Transmission",
         color = "Transmission") +
    scale_colour_manual(labels = c("Automatic", "Manual"),
                        values = c("red", "blue"))
```



4. Plots from the selected model

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


Residuals vs Fitted
Residuals
Fitted values
Merc 240D
Fiat 128
Datsun 710
Normal Q−Q
Standardized residuals
Theoretical Quantiles
Fiat 128
Merc 240D
Datsun 710
Scale−Location
√|Standardized residuals|
Fitted values
Merc 240D
Fiat 128
Datsun 710
Residuals vs Leverage
Standardized residuals
Leverage
Cook's distance
Fiat 128
Chrysler Imperial
Maserati Bora
0.5
0.5