

Regression Models Project Report

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Executive Summary

In the present project, we have attempted to answer the question of whether manual or automatic transmission is a better choice for efficient fuel usage in cars. The data used for this analysis come from the 1974 Motor Trend US Magazine. We have performed hypothesis testing and fitted linear models to establish and quantify the relationship between MPG and type of transmission. It turned out that the weight of the car was a significant confounder in our analysis, and the choice of manual or automatic depends on it.

Exploratory Data Analysis

First, we load the data set `mtcars` and change some variables from `numeric` class to `factor` class.

```
library(ggplot2)
data(mtcars)
mtcars[1:3, ] # Sample Data
```

```
##           mpg cyl disp  hp drat   wt  qsec vs am gear carb
## Mazda RX4      21.0   6  160 110 3.90 2.620 16.46  0  1    4    4
## Mazda RX4 Wag  21.0   6  160 110 3.90 2.875 17.02  0  1    4    4
## Datsun 710     22.8   4  108  93 3.85 2.320 18.61  1  1    4    1
```

```
dim(mtcars)
```

```
## [1] 32 11
```

```
mtcars$cyl <- as.factor(mtcars$cyl)
mtcars$vs <- as.factor(mtcars$vs)
mtcars$am <- factor(mtcars$am)
mtcars$gear <- factor(mtcars$gear)
mtcars$carb <- factor(mtcars$carb)
attach(mtcars)
```

```
## The following object is masked from package:ggplot2:
##
##      mpg
```

Then, we do some basic exploratory data analyses. Please refer to the **Appendix: Figures** section for the plots. According to the box plot, we see that manual transmission yields higher values of MPG in general. And as for the pair graph, we can see some higher correlations between variables like “wt”, “disp”, “cyl” and “hp”.

Inference

At this step, we make the null hypothesis as the MPG of the automatic and manual transmissions are from the same population (assuming the MPG has a normal distribution). We use the two sample T-test to show it.

```
result <- t.test(mpg ~ am)
result$p.value
```

```
## [1] 0.001373638
```

```
result$estimate
```

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

Since the p-value is 0.00137, we reject our null hypothesis. So, the automatic and manual transmissions are from different populations. And the mean for MPG of manual transmitted cars is about 7 more than that of automatic transmitted cars.

Regression Analysis

First, we fit the full model as the following.

```
fullModel <- lm(mpg ~ ., data=mtcars)
summary(fullModel) # results hidden
```

This model has the Residual standard error as 2.833 on 15 degrees of freedom. And the Adjusted R-squared value is 0.779, which means that the model can explain about 78% of the variance of the MPG variable. However, none of the coefficients are significant at 0.05 significant level.

Then, we use backward selection to select some statistically significant variables.

```
stepModel <- step(fullModel, k=log(nrow(mtcars)))
summary(stepModel) # results hidden
```

This model is “mpg ~ wt + qsec + am”. It has the Residual standard error as 2.459 on 28 degrees of freedom. And the Adjusted R-squared value is 0.8336, which means that the model can explain about 83% of the variance of the MPG variable. All of the coefficients are significant at 0.05 significant level.

Please refer to the **Appendix: Figures** section for the plots again. According to the scatter plot, it indicates that there appear to be an interaction term between “wt” variable and “am” variable, since automatic cars tend to weigh heavier than manual cars. Thus, we have the following model including the interaction term:

```
amIntWtModel<-lm(mpg ~ wt + qsec + am + wt:am, data=mtcars)
summary(amIntWtModel) # results hidden
```

This model has the Residual standard error as 2.084 on 27 degrees of freedom. And the Adjusted R-squared value is 0.8804, which means that the model can explain about 88% of the variance of the MPG variable. All of the coefficients are significant at 0.05 significant level. This is a pretty good one.

Next, we fit the simple model with MPG as the outcome variable and Transmission as the predictor variable.

```
amModel<-lm(mpg ~ am, data=mtcars)
summary(amModel) # results hidden
```

It shows that on average, a car has 17.147 mpg with automatic transmission, and if it is manual transmission, 7.245 mpg is increased. This model has the Residual standard error as 4.902 on 30 degrees of freedom. And the Adjusted R-squared value is 0.3385, which means that the model can explain about 34% of the variance of the MPG variable. The low Adjusted R-squared value also indicates that we need to add other variables to the model.

Finally, we select the final model.

```
anova(amModel, stepModel, fullModel, amIntWtModel)
confint(amIntWtModel) # results hidden
```

We end up selecting the model with the highest Adjusted R-squared value, “mpg ~ wt + qsec + am + wt:am”.

```
summary(amIntWtModel)$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

Thus, the result shows that when “wt” (weight lb/1000) and “qsec” (1/4 mile time) remain constant, cars with manual transmission add $14.079 + (-4.141) \cdot \text{wt}$ more MPG (miles per gallon) on average than cars with automatic transmission. That is, a manual transmitted car that weighs 2000 lbs have 5.797 more MPG than an automatic transmitted car that has both the same weight and 1/4 mile time.

Residual Analysis and Diagnostics

Please refer to the **Appendix: Figures** section for the plots. According to the residual plots, we can verify the following underlying assumptions:

1. The Residuals vs. Fitted plot shows no consistent pattern, supporting the accuracy of the independence assumption.
2. The Normal Q-Q plot indicates that the residuals are normally distributed because the points lie closely to the line.
3. The Scale-Location plot confirms the constant variance assumption, as the points are randomly distributed.
4. The Residuals vs. Leverage argues that no outliers are present, as all values fall well within the 0.5 bands.

As for the Dfbetas, the measure of how much an observation has effected the estimate of a regression coefficient, we get the following result:

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

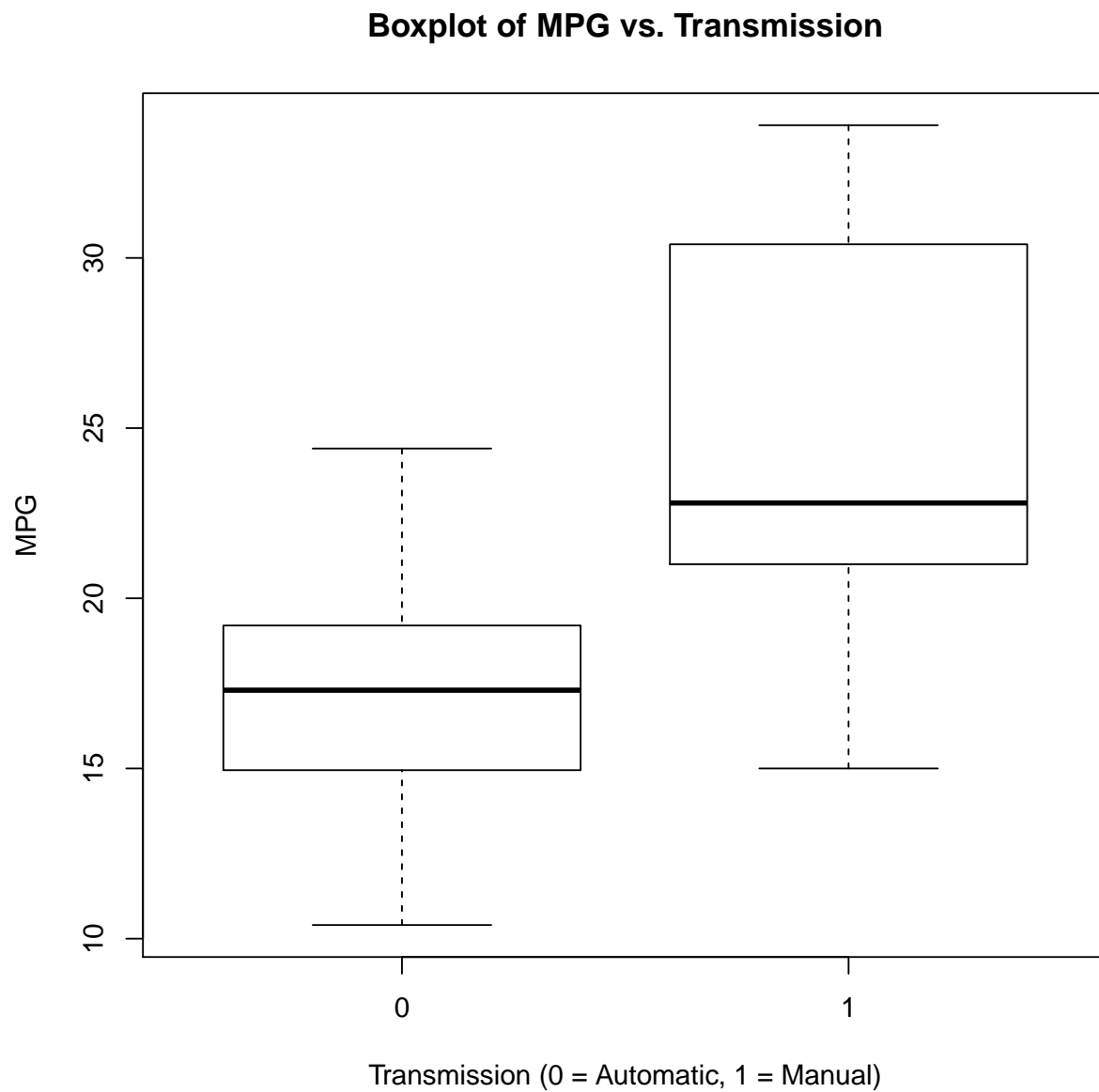
```
## [1] 0
```

Therefore, the above analyses meet all basic assumptions of linear regression and well answer the questions.

Appendix: Figures

1. Boxplot of MPG vs. Transmission

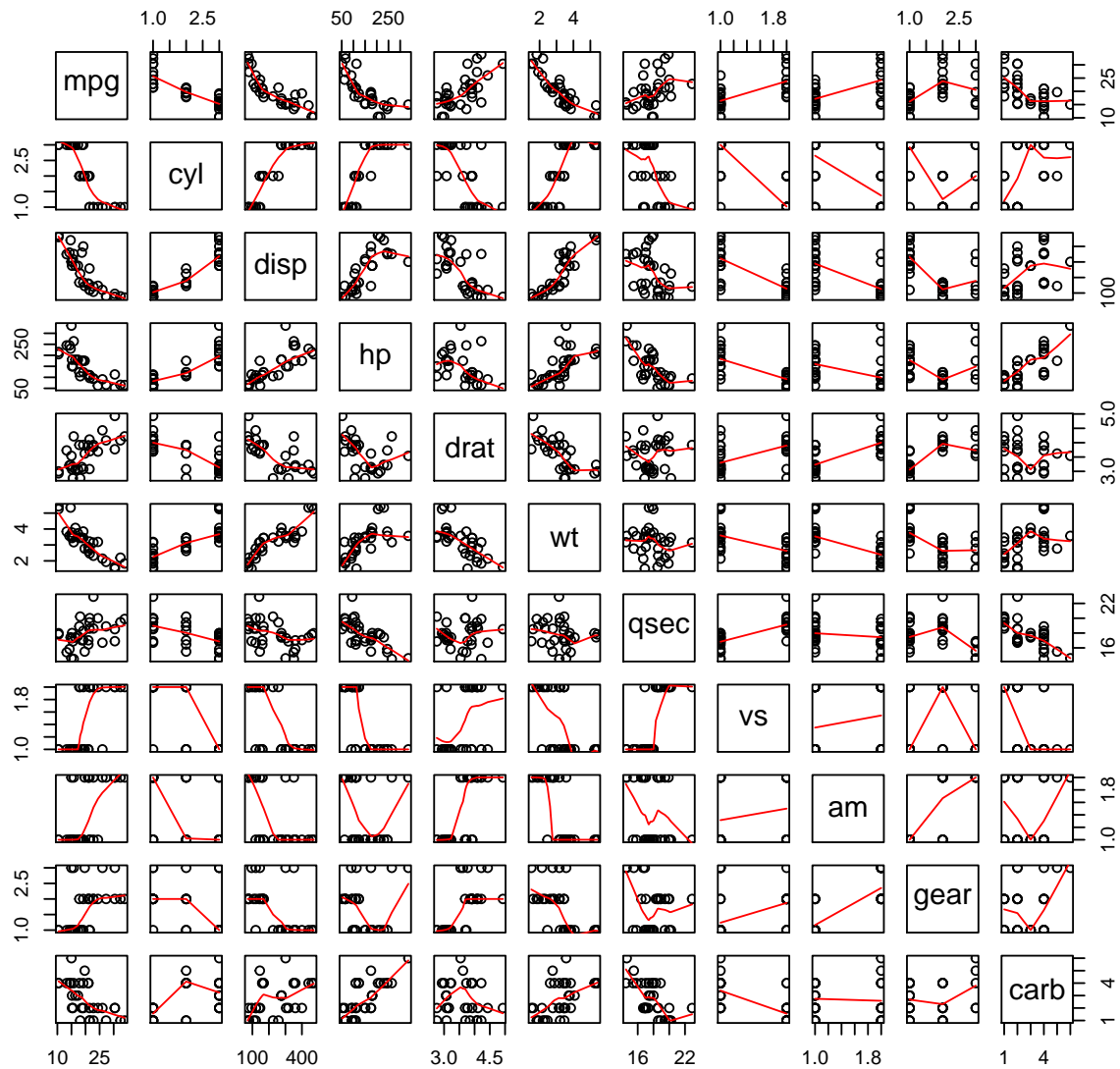
```
boxplot(mpg ~ am, xlab="Transmission (0 = Automatic, 1 = Manual)", ylab="MPG",  
        main="Boxplot of MPG vs. Transmission")
```



2. Pair Graph of Motor Trend Car Road Tests

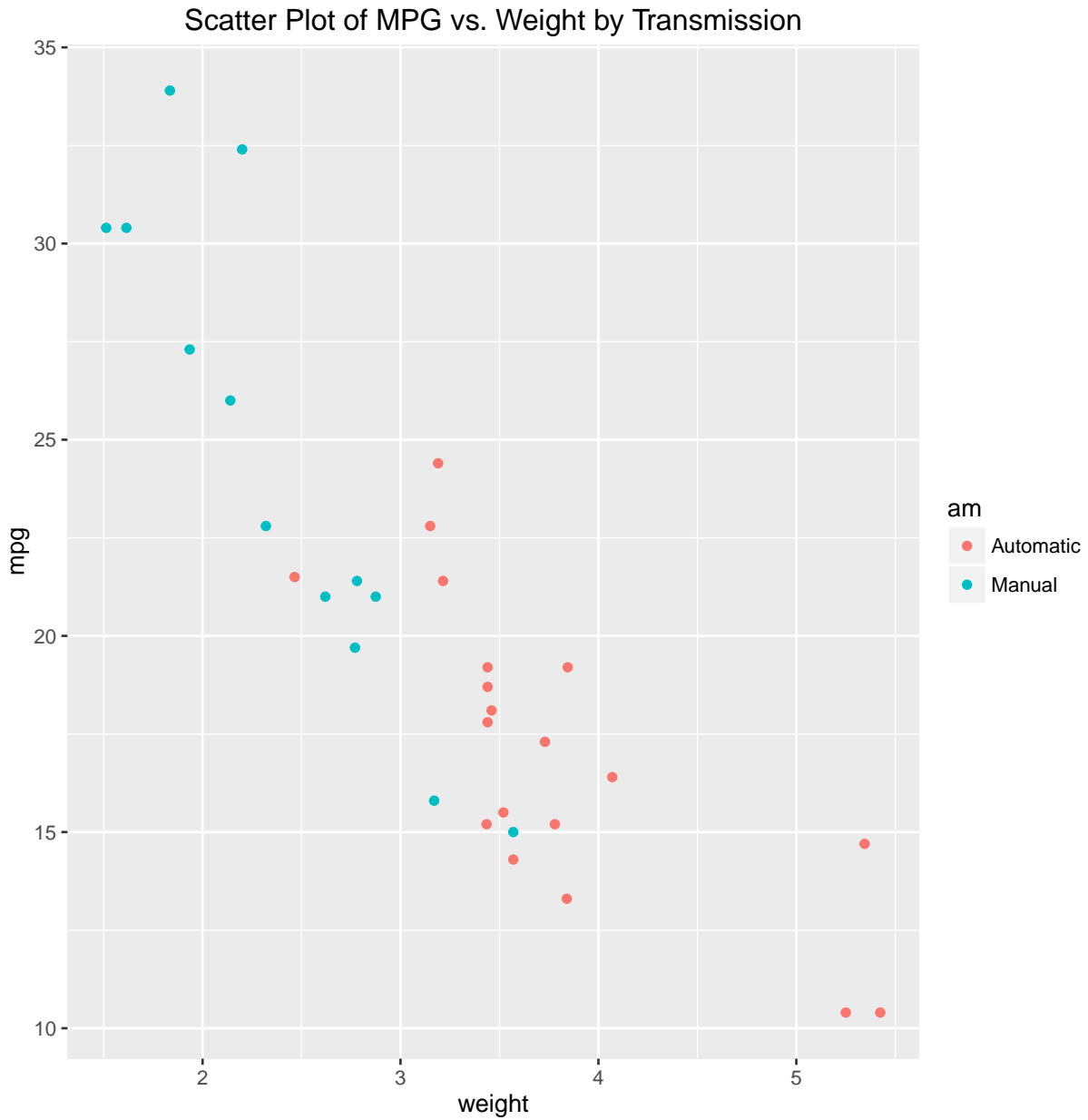
```
pairs(mtcars, panel=panel.smooth, main="Pair Graph of Motor Trend Car Road Tests")
```

Pair Graph of Motor Trend Car Road Tests



3. Scatter Plot of MPG vs. Weight by Transmission

```
ggplot(mtcars, aes(x=wt, y=mpg, group=am, color=am, height=3, width=3)) + geom_point() +
scale_colour_discrete(labels=c("Automatic", "Manual")) +
xlab("weight") + ggtitle("Scatter Plot of MPG vs. Weight by Transmission")
```



4. Residual Plots

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

