Regression: MotorTrend MPG

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7/20/2017

Executive Summary

We were asked by Motor Trend to help understand the relationship between a number of variables, predictors, and miles-per-gallon (MPG), outcome, Specifically, were are asked to answer the following two questions:

- Is an automatic or manual transmission better for MPG?
- Quantify the MPG difference between automatic and manual transmissions"

Under a simple linear regression model, it would appear that a manual transmission adds more than 7 mpg over an automatic. Using additional variables to our regression model, we conclude that switching from an automatic to manual adds 1.8 mpg, all else equal.

Data Processing

Use data(mtcars) to load the R dataset into the current enviromnent.

```
data(mtcars)
mtcars2 <- mtcars
mtcars2$am <- as.factor(mtcars2$am)
mtcars2$cyl <- as.factor(mtcars2$cyl)
```

Exploratory Data Analysis

To obtain a high-level insight to the relationship of the different variables in the data set, we created a panel plot and correlation matrix (see Appendix: Figure 1 & Figure 2) to understand the relationships. We find that the variables cyl, disp, hp, and wt have the strongest relationship with mpg. The variables drat, vs, and am are slightly less connected. We use this information to help assess our regression analysis results.

Regression Analysis

Here we look build and compare various regression models to identify a model that best fits data. We use several metrics to evaluate our model fit, including: adjusted r-square, residual squared error (sigma), and p-values. We also use ANOVA and an analysis of the residuals to evaluate the model.

Regression Models

Approached building mdoels through process of adding variables that contribute significantly to predicting MPG.

```
fit1 <- lm(mpg ~ am, data = mtcars2)
fit10 <- lm(mpg ~ ., data = mtcars2)
bestfit <- step(fit10, direction = "both")   ## stepwise process to identify best fit

## Obtained by manually adding / removing variables (using correlations as guide)
fit3 <- lm(mpg ~ am + wt + cyl, data = mtcars2)
fit4 <- lm(mpg ~ am + wt + cyl + hp, data = mtcars2)
```

Comparison of Regression Models

Two comparisons performed to evaluate the best model. The first is a comparison of the r.square and p-value for each model. Then, we perform ANOVA to evaluate whether model is significantly better.

Exhbit 1: R.Square, Sigma, and P-value Comparisons

```
##     model r.squared adj.r.squared  sigma statistic p.value df
## 1    fit1    0.3598        0.3385 4.9020   16.8603   3e-04  2
## 2    fit3    0.8375        0.8134 2.6032   34.7917   0e+00  5
## 3    fit4    0.8659        0.8401 2.4101   33.5712   0e+00  6
## 4 bestfit    0.8497        0.8336 2.4588   52.7496   0e+00  4
## 5   fit10    0.8816        0.8165 2.5819   13.5381   0e+00 12
```

Exhibit 2: ANOVA

The findings provided below for Model 4 produce a p-value of 0.02693, which indicates that this model is significant. These variables further contribute to the accuracy of the model.

```
## Analysis of Variance Table
##
## Model 1: mpg ~ am
## Model 2: mpg ~ am + wt + cyl
## Model 3: mpg ~ am + wt + cyl + hp
##   Res.Df    RSS Df Sum of Sq       F    Pr(>F)
## 1     30 720.90
## 2     27 182.97  3    537.93 30.8692 1.008e-08 ***
## 3     26 151.03  1     31.94  5.4991   0.02693 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Residuals & Diagnostics

A panel plot of residuals (see Appendix: Figure 3). Understanding residuals is critical to understanding how well the regression model fits the data, goodness of fit. The different plots provide some insight to how closely the regression line fits the data. Although a few “outlier” points noted, the results seem to validate model fit.

1. Residuals vs Fitted: This plot shows if residuals have non-linear patterns. Want to see that the residuals are fairly well-distributed around the fitted line, and no particular pattern exists.
2. Normal Q-Q: This plot shows if residuals are normally distributed. It’s good fit if residuals are lined closely the straight dashed line.

3. Scale-Location: Use to check the assumption of equal variance (homoscedasticity). Ideally, we would see points that are equally spread around a horizontal line along the entire range of predictors.
4. Cooks distance: The purpose of this plot is identify may be considered outliers. The "Cooks distance" is considerably different from others. These points may be influential against the regression line, changing intercept and/or slope.

High Leverage/Influential Data Points

We use the function influence.measures() to help identify points/observations that may need to be considered for its influence on coefficients.

```
## Potentially influential observations of
##   lm(formula = mpg ~ am + wt + cyl + hp, data = mtcars2) :
##
##                     dfb.1_ dfb.am1 dfb.wt dfb.cyl6 dfb.cyl8 dfb.hp dffit
## Lincoln Continental  0.16  -0.09   -0.19   0.06     0.04     0.04  -0.22
## Maserati Bora       -0.18   0.04   -0.09  -0.14    -0.25     0.53   0.70
##                     cov.r   cook.d hat
## Lincoln Continental  1.74_*  0.01   0.29
## Maserati Bora        2.10_*  0.08   0.47
```

Statistical Inference

To provide additional perspective on the strength of the model in predicting, a comparison of the actual MPG to the fitted mpg and associated 95% confidence interval (see Appendix: Figure 4) to look at how well the model estimated results. While there are a few instances (see Appendix: Figure 5) where the actual MPG falls outside the 95% confidence interval, a majority fit the model.

Conclusion

The regression model, fit4, provides the best fit, explaining 84% of the changes in MPG. Outline of coefficients:
1. Intercept [33.71] - estimate of MPG for an average wt & hp car with 4 cyl car and automatic transmission
2. am1 - MPG increases 1.81 mpg for switching to a manual transmission, all else equal
3. wt - reduces MPG by 2.5 for a 1 unit (1,000 lbs) change in the weight of a car, all else equal
4. cyl6 - a switch from a 4 cyl to 6 cyl decreases MPG by 3.03, all else equal
5. cyl8 - a switch from a 4 cyl to 8 cyl decreases MPG by 2.16, all else equal (less than 6 cyl?) 6. hp - a 1 unit change in hp reduces MPG by 0.03, all else equal

Regression Coefficients

```
## (Intercept)         am1          wt        cyl6        cyl8          hp
##       33.71        1.81       -2.50       -3.03       -2.16       -0.03
```

Although there may more that can be learned about interaction between cyl (cyl8) and hp, this model produces a fairly reliable approach to predicting the MPG of a car. With a larger population and/or more detailed look at values within a variable, it may be possible to create a better model. This creates the risk of overfitting to reduce residuals, but not necessarily improving the applicability of the model.

Appendix

Figure 1 (Panel Plot): Illustrate the relationship of each variable

This panel plot provides a quick, high-level, illustration of a variable within the dataset against each other variable in the dataset. The pu

```
pairs(mtcars, panel = panel.smooth, main = "MT Cars Data", col = 3)
```

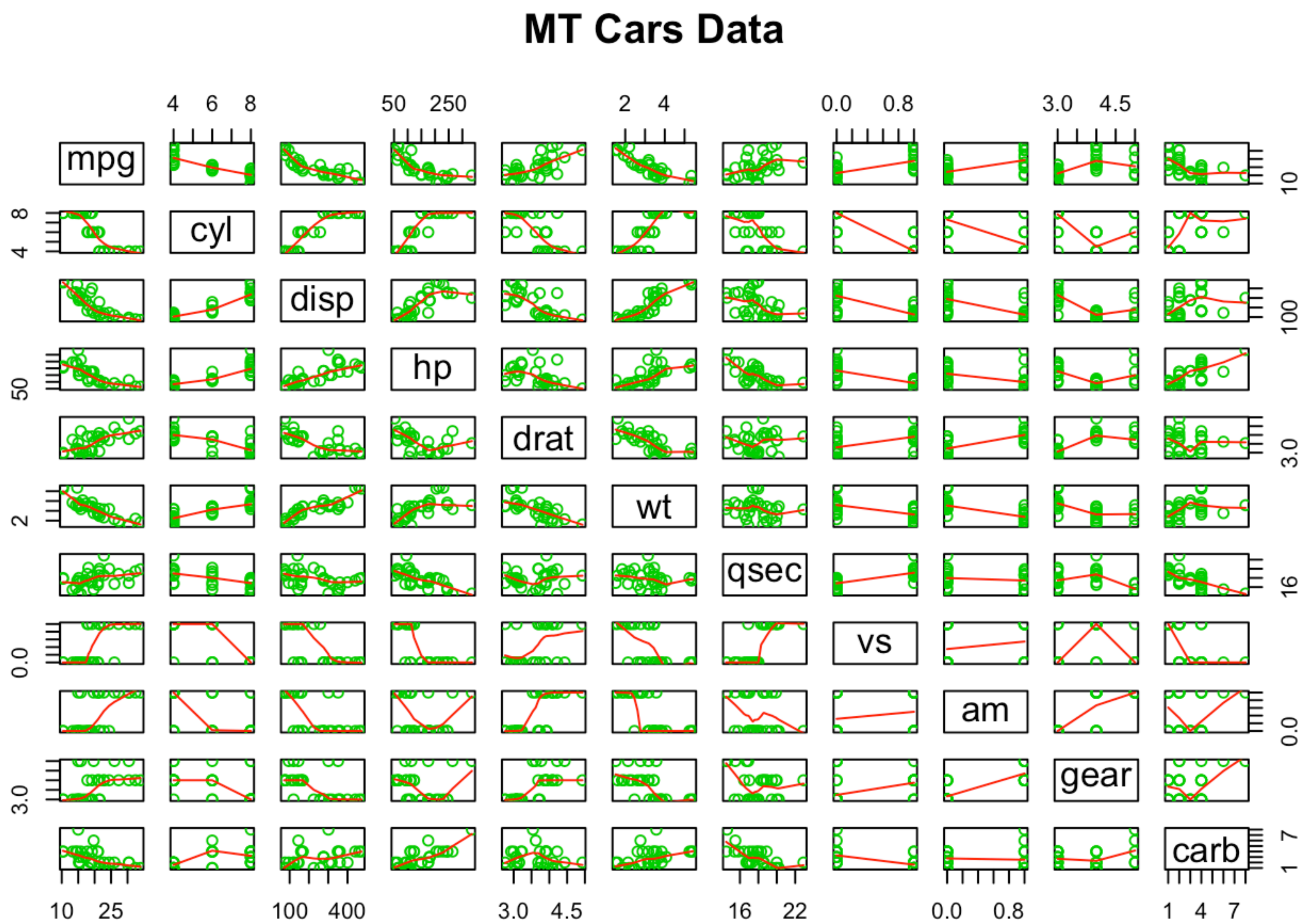

Figure 2: Correlation Factor Matrix

```
par(mar = c(5,4,2,1))
mtcars.cor <- cor(mtcars)
corrplot(mtcars.cor, method = "number", type = "upper", add = FALSE,
                    order = "original", is.corr = TRUE)
```

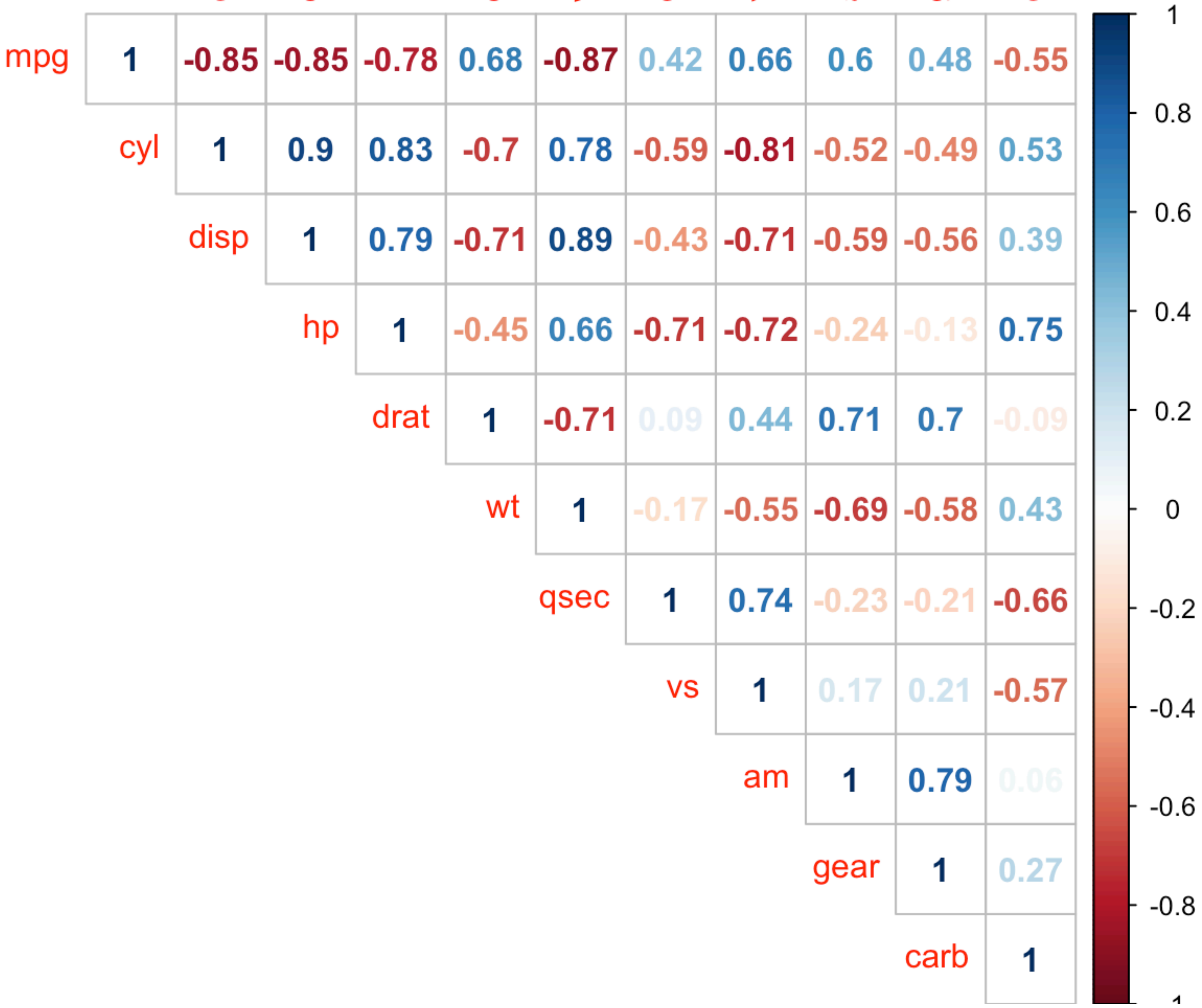

Figure 3: Regression Model Residuals

Figure 4: Regression Model Confidence Interval

```
fit4.confint <- round(predict(fit4, mtcars2, interval = "confidence", level = 0.95),
2)
actual <- mtcars2[,1]
fit4.compare <- as.data.frame(cbind(actual, fit4.confint))
fit4.compare
```

```
##                     actual   fit   lwr   upr
## Mazda RX4             21.0 22.41 20.02 24.81
## Mazda RX4 Wag         21.0 21.78 19.30 24.25
## Datsun 710            22.8 26.74 25.08 28.40
## Hornet 4 Drive        21.4 19.12 16.99 21.24
## Hornet Sportabout     18.7 17.34 15.50 19.17
## Valiant               18.1 18.67 16.59 20.74
## Duster 360            14.3 14.76 12.56 16.96
## Merc 240D             24.4 23.75 21.54 25.97
## Merc 230              22.8 22.79 20.41 25.17
## Merc 280              19.2 18.14 16.01 20.26
## Merc 280C             17.8 18.14 16.01 20.26
## Merc 450SE            16.4 15.60 14.09 17.11
## Merc 450SL            17.3 16.45 14.88 18.03
## Merc 450SLC           15.2 16.33 14.78 17.88
## Cadillac Fleetwood    10.4 11.85  9.38 14.33
## Lincoln Continental   10.4 11.10  8.41 13.78
## Chrysler Imperial     14.7 10.81  8.28 13.35
## Fiat 128              32.4 27.91 26.10 29.71
## Honda Civic           30.4 29.82 27.83 31.81
## Toyota Corolla        33.9 28.85 27.08 30.62
## Toyota Corona         21.5 24.44 21.83 27.05
## Dodge Challenger      15.5 17.94 15.87 20.01
## AMC Javelin           15.2 18.15 16.03 20.27
## Camaro Z28            13.3 14.09 12.15 16.03
## Pontiac Firebird      19.2 16.33 14.75 17.90
## Fiat X1-9             27.3 28.57 26.82 30.32
## Porsche 914-2         26.0 27.25 25.65 28.86
## Lotus Europa          30.4 28.11 26.03 30.19
## Ford Pantera L        15.8 16.96 14.59 19.34
## Ferrari Dino          19.7 19.95 17.57 22.33
## Maserati Bora         15.0 13.68 10.28 17.08
## Volvo 142E            21.4 25.08 23.07 27.09
```

Figure 5: Regression Model Observations outside Confidence Interval

```
fit4.confint <- round(predict(fit4, mtcars2, interval = "confidence", level = 0.95),
2)
actual <- mtcars2[,1]
fit4.compare <- as.data.frame(cbind(actual, fit4.confint))
fit4.compare$outlier <- ifelse(fit4.compare$actual < fit4.compare$lwr | fit4.compare$
actual > fit4.compare$upr, "Y","N")
fit4.outlier <- subset(fit4.compare, outlier == "Y")
select(fit4.outlier, actual, fit, lwr, upr)
```

```
##                     actual   fit   lwr   upr
## Datsun 710            22.8 26.74 25.08 28.40
## Hornet 4 Drive        21.4 19.12 16.99 21.24
## Chrysler Imperial     14.7 10.81  8.28 13.35
## Fiat 128              32.4 27.91 26.10 29.71
## Toyota Corolla        33.9 28.85 27.08 30.62
## Toyota Corona         21.5 24.44 21.83 27.05
## Dodge Challenger      15.5 17.94 15.87 20.01
## AMC Javelin           15.2 18.15 16.03 20.27
## Pontiac Firebird      19.2 16.33 14.75 17.90
## Lotus Europa          30.4 28.11 26.03 30.19
## Volvo 142E            21.4 25.08 23.07 27.09
```