Analysis of Automobile Prices

Graeme Malcolm, March 2017

Executive Summary

This document presents an analysis of data concerning automobiles and their prices. The analysis is based on 216 observations of automobile data, each containing specific characteristics of an automobile and its price.

After exploring the data by calculating summary and descriptive statistics, and by creating visualizations of the data, several potential relationships between automobile characteristics and price were identified. After exploring the data, a predictive model to classify automobiles into two pricing categories was created, and finally a regression model to predict an automobile price from its features was created.

After performing the analysis, the author presents the following conclusions:

While many factors can help indicate the price of an automobile, significant features found in this analysis were:

- **Make** – the manufacturer of the vehicle. The price of automobiles for some specific manufacturers are more expensive than automobiles with comparable features from other manufacturers.
- **Cylinders** – the number of cylinders in the vehicle engine. Cars with four or less cylinders tend to have a lower mean price than cars with five to six cylinders, which in turn tend to cost less than cars with eight or more cylinders.
- **Horsepower** – the maximum power output of the vehicle engine. Vehicles with a higher horsepower tend to be more expensive.
- **City MPG** – Fuel efficiency during city driving. There appears to be a negative correlation between price and city MPG, in which less expensive cars tend to have greater fuel efficiency.
- **Drive Wheels** – the wheels powered by the engine. Cars with a rear-wheel drive (RWD) system have a higher mean price than those with front-wheel drive (FWD) and four-wheel drive (4WD).

Initial Data Exploration

The initial exploration of the data began with some summary and descriptive statistics.

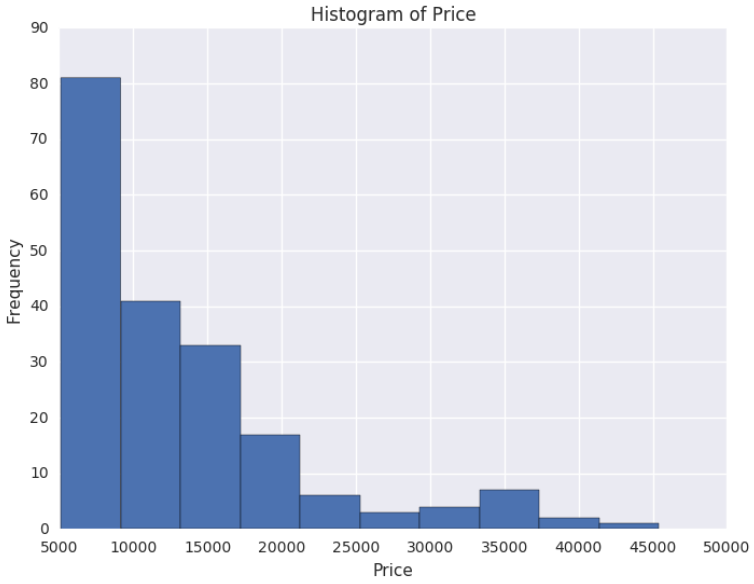
Individual Feature Statistics

Summary statistics for minimum, maximum, mean, median, standard deviation, and distinct count were calculated for numeric columns, and the results taken from 216 observations are shown here:

Column	Min	Max	Mean	Median	Std Dev	DCount
Wheel-base	86.6	12.9	99.15	97.2	6.1316	53
Length	141.1	208.1	174.8005	173.45	12.4494	75
Width	60.3	72.3	66.0125	65.66	2.1465	44
Height	47.8	59.8	53.8528	54.1	2.4805	49
Curb Weight	1488	4066	2580.1296	2459	518.5688	171
Engine Size	61	326	127.6898	120	40.7767	44

Bore	2.54	3.94	3.347	3.33	0.2809	38
Stroke	2.07	4.17	3.2498	3.27	0.3104	36
Compression	7	23	10.1469	9	3.9791	32
Horsepower	48	288	105.4766	97	39.3322	59
Peak RPM	4150	6600	5133.8785	5200	470.3753	23
City MPG	13	49	25.0139	14	6.4717	29
Highway MPG	16	54	30.5	30	6.8172	30
Price	5118	45400	13459.0943	10921.5	7845.3586	186

Since **Price** is of interest in this analysis, it was noted that the mean and median of this value are significantly different and that the comparatively large standard deviation indicates that there is considerable variance in the prices of the automobiles. A histogram of the **Price** column shows that the price values are right-skewed – in other words, most cars are priced at the lower end of the price range, as shown here:



In addition to the numeric values, the automobile observations include categorical features, including:

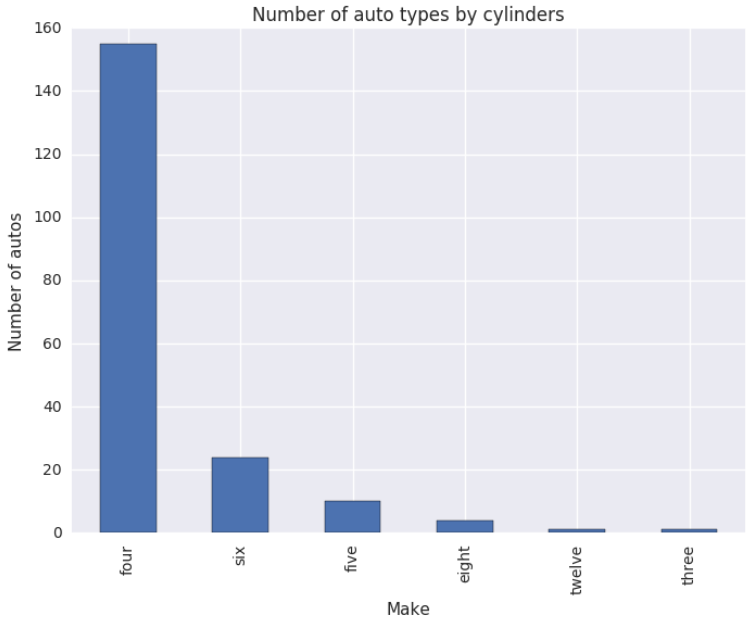
- **Make** – One of 22 manufacturers.
- **Fuel Type** – Gas or Diesel.
- **Aspiration** – Std or Turbo.
- **Number of Doors** – four or two
- **Body Style** – Sedan, Hatchback, Wagon, Hardtop, or Convertible.
- **Drive Wheels** – FWD, RWD, or 4WD.
- **Engine Location** – Front or Rear.
- **Engine Type** – ohc, ohcf, ohcv, dohc, l, rotor, or dohcv
- **Number of Cylinders** – two, three, four, five, six, eight, or twelve
- **Fuel System** – mpfi, 2bbl, idi, 1bbl, spdi, 4bbl, mfi, spfi

Bar charts were created to show frequency of these features, and indicate the following:

- Gas cars are more common than diesel cars.
- Standard aspiration cars are more common than turbo cars

- Sedans are the most common body style, followed by hatchbacks and wagons; hardtops and convertibles are relatively uncommon
- Four-wheel drive cars are much less common than front or rear wheel drive cars.
- Rear-engine cars are extremely uncommon.
- The vast majority of cars have ohc engines.
- Most cars have four cylinders, with very small frequencies for each of the other values.
- Most cars have a fuel type of mpfi, with 2bbl the next most common. All other types have much lower frequencies.

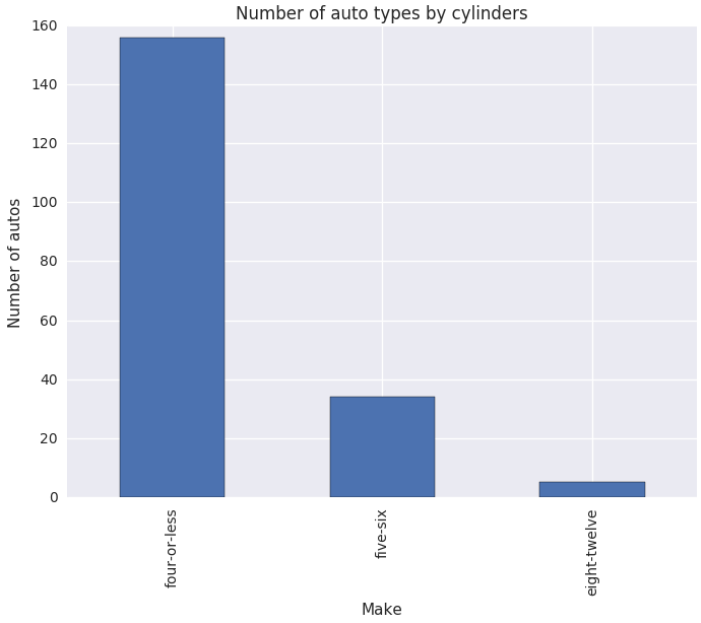
One key observation is that the number of cylinders is usually four, and that other values have low frequencies, shown here:



It was decided that since these categorical values represent numeric counts, they could be combined into fewer categories that represent ranges of values as follows:

- Four or less
- Five or Six
- Eight or Twelve

This resulted in a smaller range of categories, as shown here:

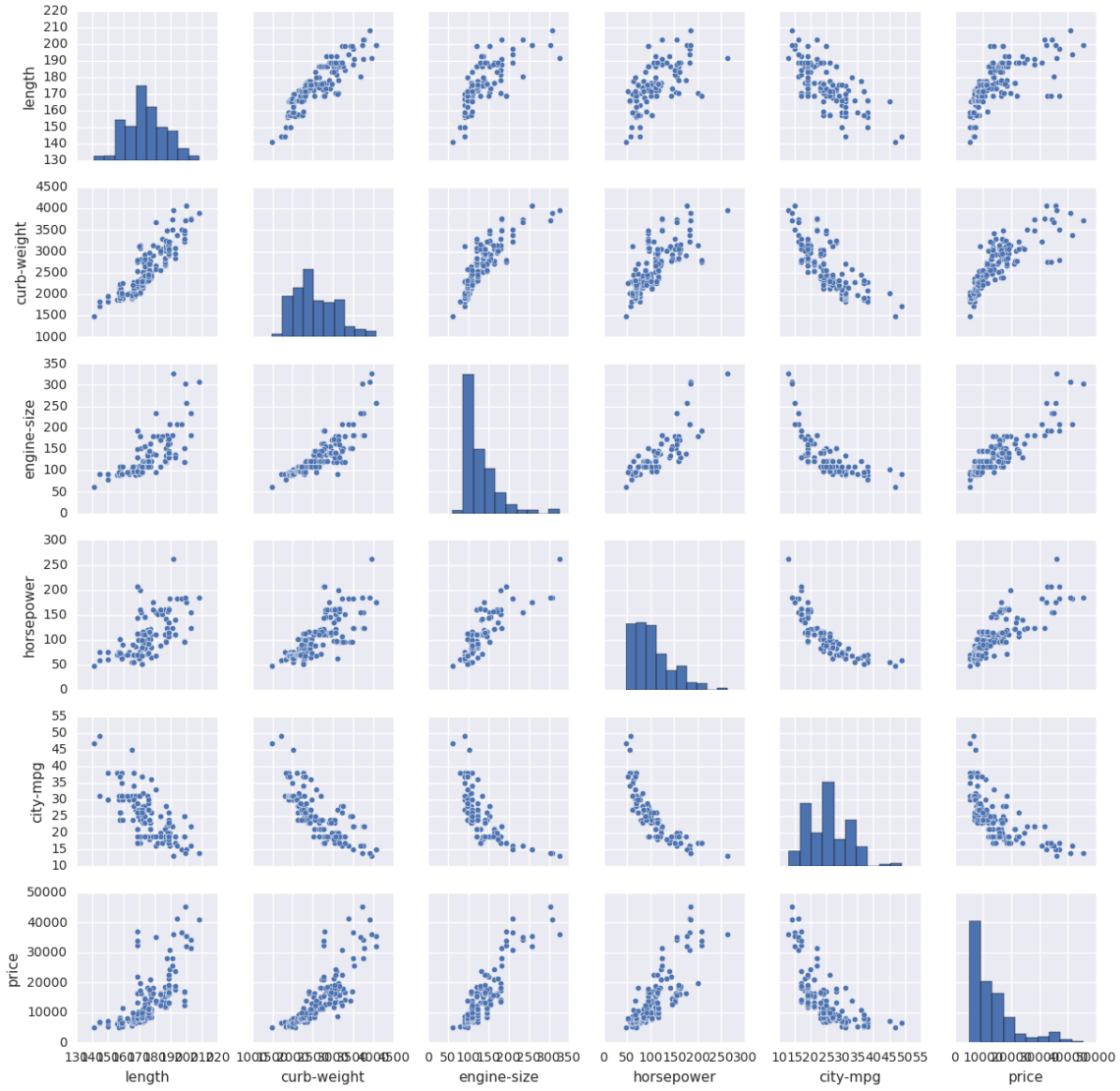


Correlation and Apparent Relationships

After exploring the individual features, an attempt was made to identify relationships between features in the data – in particular, between **Price** and the other features.

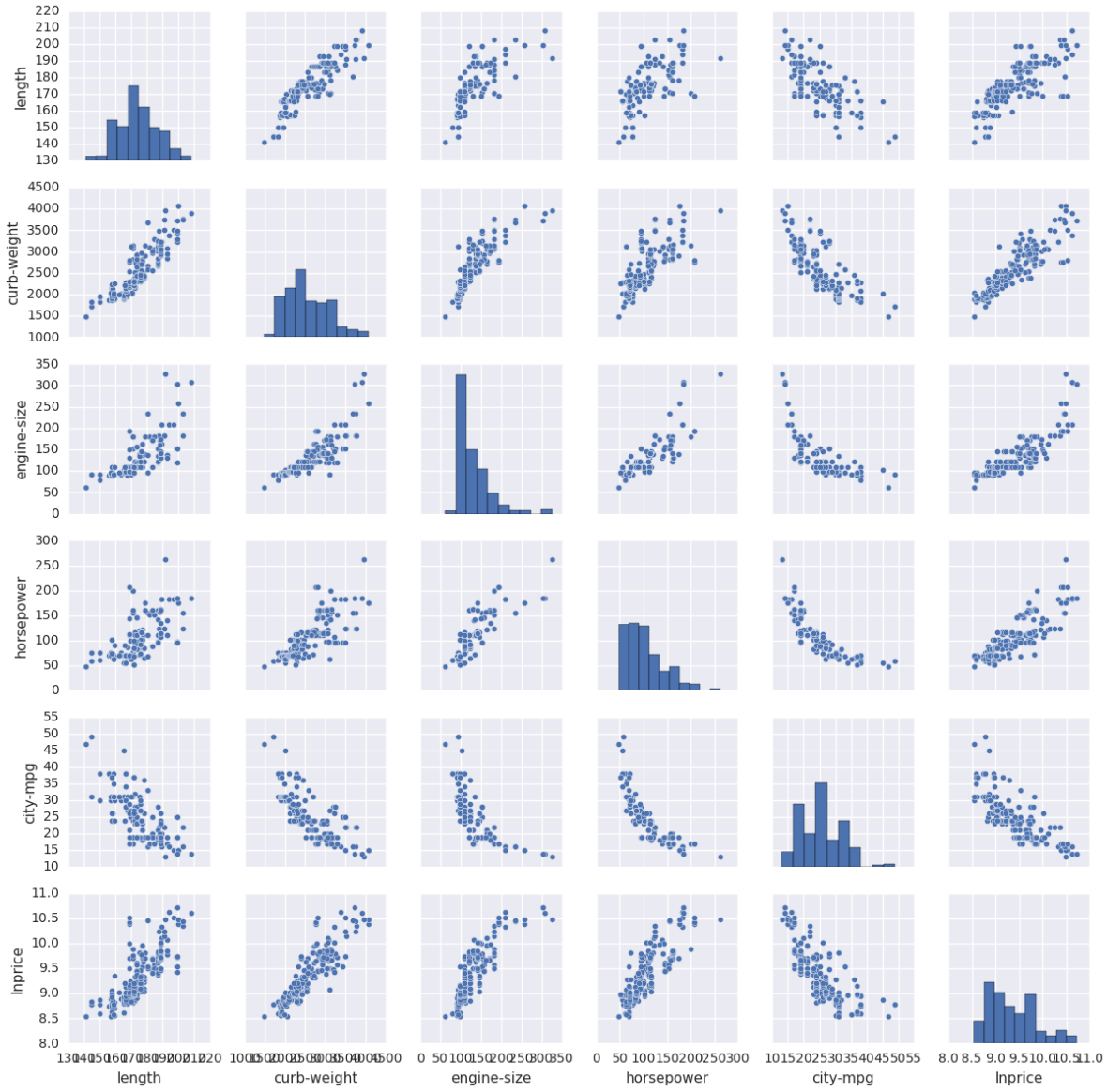
Numeric Relationships

The following scatter-plot matrix was generated initially to compare numeric features with one another. The key features in this matrix are shown here:



Viewing plots in the bottom row or the right-most column of this matrix shows an apparent relationship between price and other numeric features. Specifically, as length, curb-weight, engine size, and horsepower increase, so does price; and as city-mpg increases, price reduces.

It can be seen from these plots that the relationships between numeric features and price often exhibits a “curved” nature that is not quite linear. In an attempt to improve the fit of the features to price, the log normal value for price was calculated. The resulting scatter-plot matrix shows increased linearity in the relationships between log-price and the other numeric features:



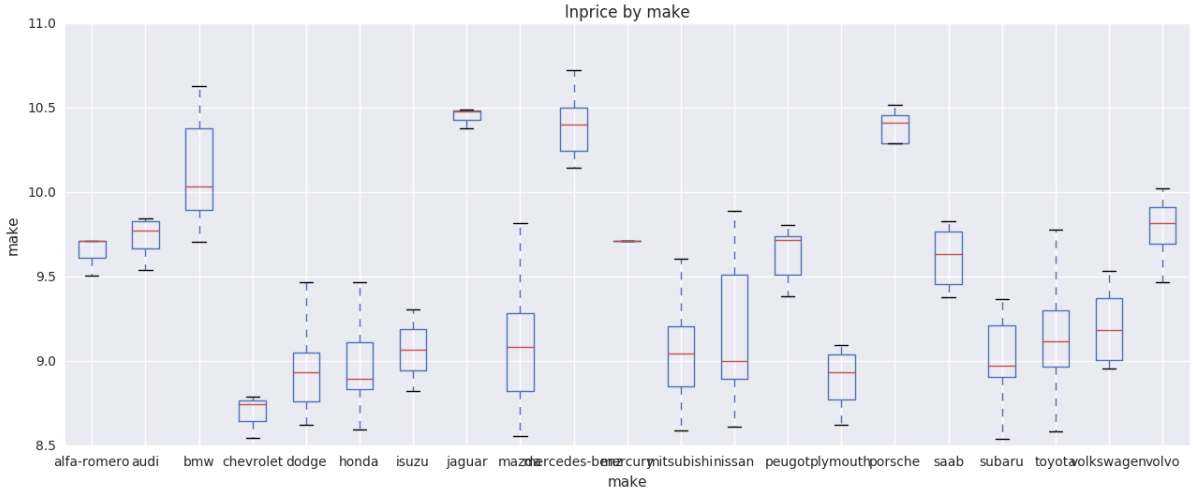
The correlation between the numeric columns was then calculated with the following results:

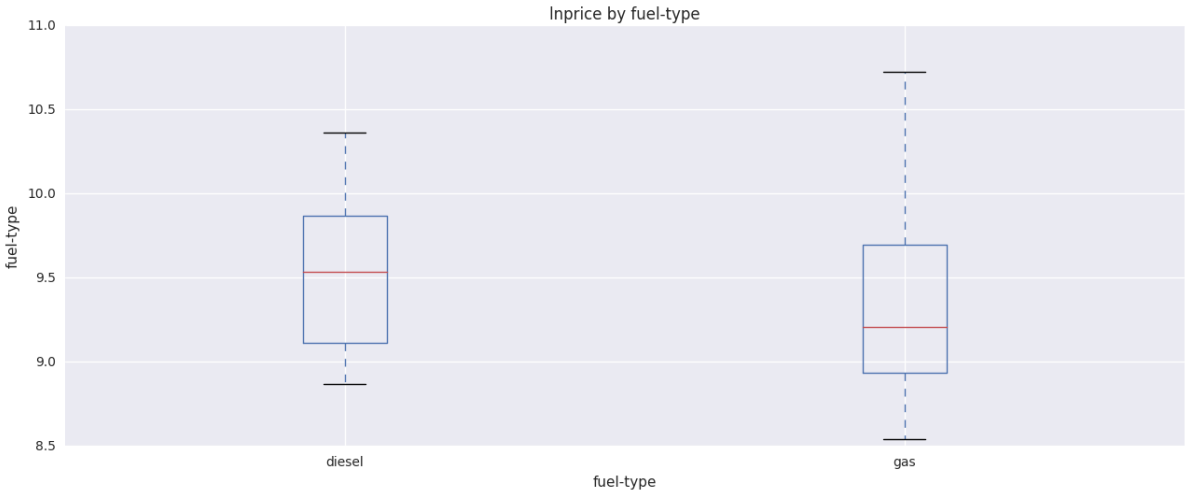
	length	curb-weight	engine-size	horsepower	city-mpg	lnprice
length	1.000000	0.881665	0.687479	0.583813	-0.689660	0.783528
curb-weight	0.881665	1.000000	0.857573	0.760285	-0.772171	0.894720
engine-size	0.687479	0.857573	1.000000	0.842691	-0.710624	0.852747
horsepower	0.583813	0.760285	0.842691	1.000000	-0.834117	0.833171
city-mpg	-0.689660	-0.772171	-0.710624	-0.834117	1.000000	-0.785839
lnprice	0.783528	0.894720	0.852747	0.833171	-0.785839	1.000000

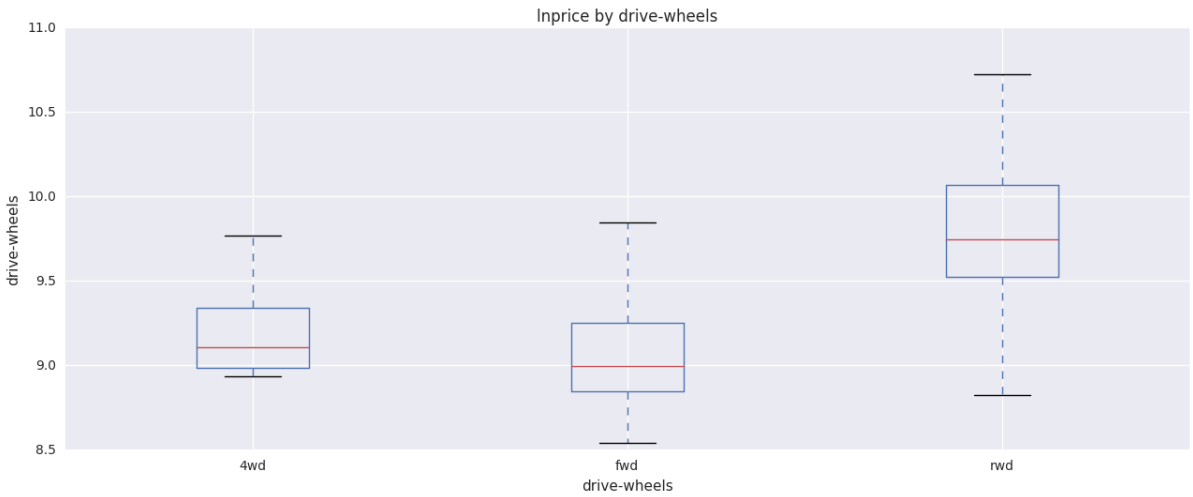
These correlations validate the plots by showing a negative correlation between city-mpg and lnprice, and moderate to strong positive correlations for the other numeric features.

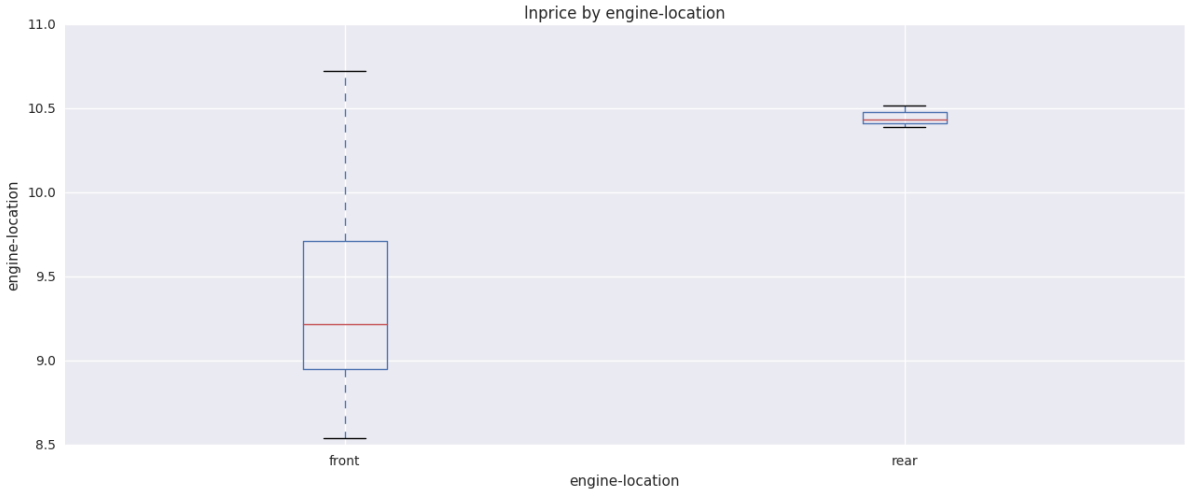
Categorical Relationships

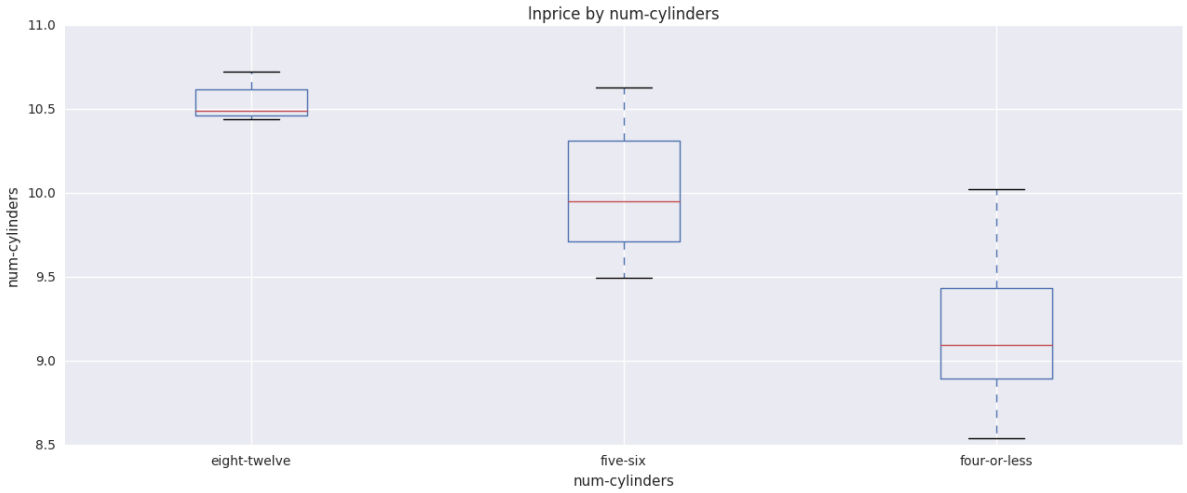
Having explored the relationship between price and numeric features, an attempt was made to discern any apparent relationship between categorical feature values and price. The following box-plots show the categorical columns that seem to exhibit a relationship with the log of price:











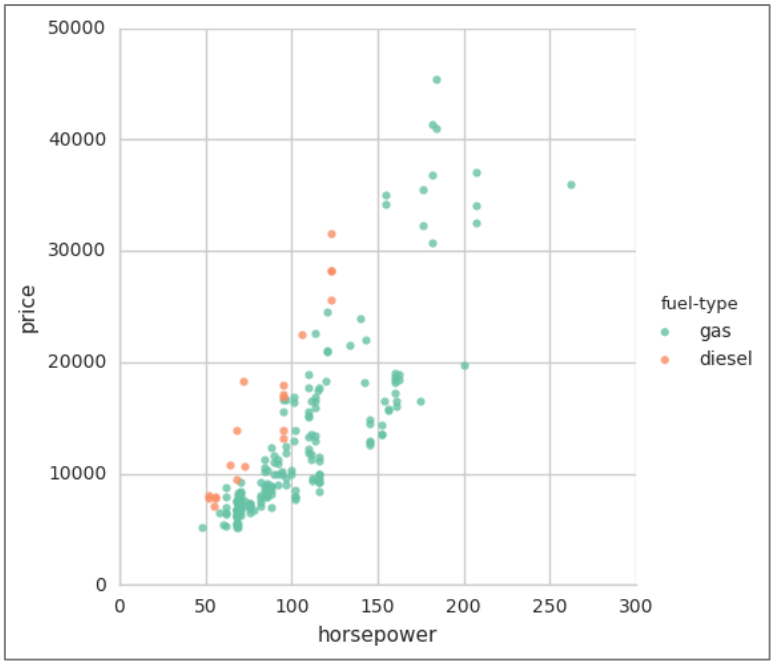
The box plots show some clear differences in terms of the median and range of price values for different categorical features. For example:

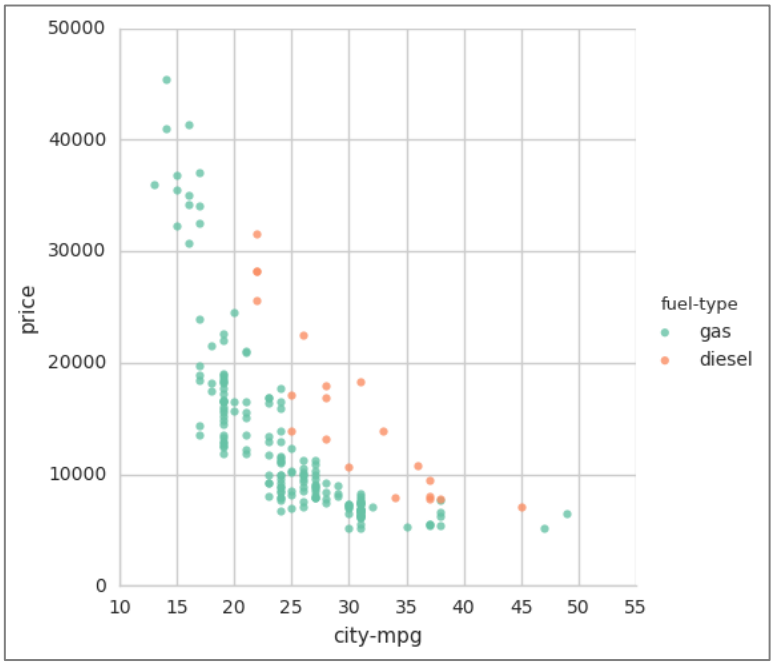
- There are a few manufacturers that typically create expensive cars, some manufactures with predominantly mid-priced cars, and some that seem to specialize in lower-priced cars.
- There are a wider range of prices for gas cars than for diesel cars, though the median price is similar for both types.
- Rear-wheel drive cars are typically more expensive than other types of car.
- Rear-engine cars are significantly more expensive than front-engine cars; and their prices fall within a smaller range (reflecting their comparative rarity).
- The three categories that were created for different numbers of cylinders seem to correspond to high, medium, and low priced ranges of cars (with some overlap).

Multi-faceted Relationships

Apparent relationships between price and individual features are helpful in determining predictive heuristics. However, relationships are often more complex, and may only become apparent when multiple features are considered in combination with one another. To help identify these more complex relationships, some faceted plots were created.

The following plots show some interesting aspects of fuel-type. Although the median price for gas and diesel cars is similar, it can be seen from these plots that fuel types can be indicative of horsepower and city-mpg, both of which are typically predictive of price.





From these plots, it can be seen that gasoline-based cars tend to have a higher horsepower, and a lower city-mpg than diesel cars; creating a cluster of low to mid-priced diesel cars compared to a wider range of gas car prices.

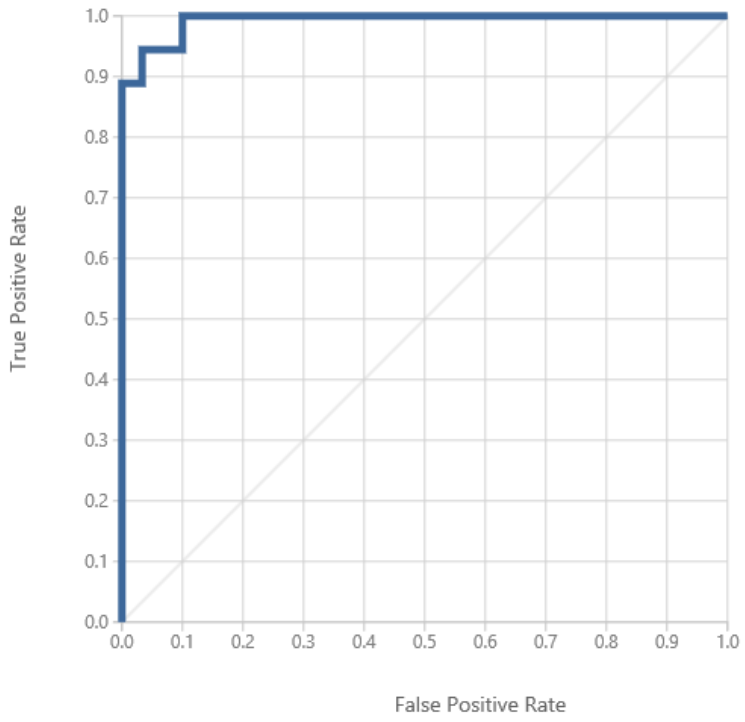
Classification of Automobiles Based on Price

Based on the analysis of the automobile price data, a predictive model to classify automobiles into two price categories: *Standard* (cars costing less than 12,000) and *Premium* (cars costing 12,000 or more).

The model was created using the Two-Class Boosted Decision Trees algorithm and trained with 65% of the data. Testing the model with the remaining 35% of the data yielded the following results:

- True Positives: 36
- True Negatives: 27
- False Positives: 3
- False Negatives: 0

The Received Operator Characteristic (ROC) curve for the model is shown here, with the blue line indicating the model's performance at varying classification threshold values, and the diagonal line showing the expected results of a random guess:



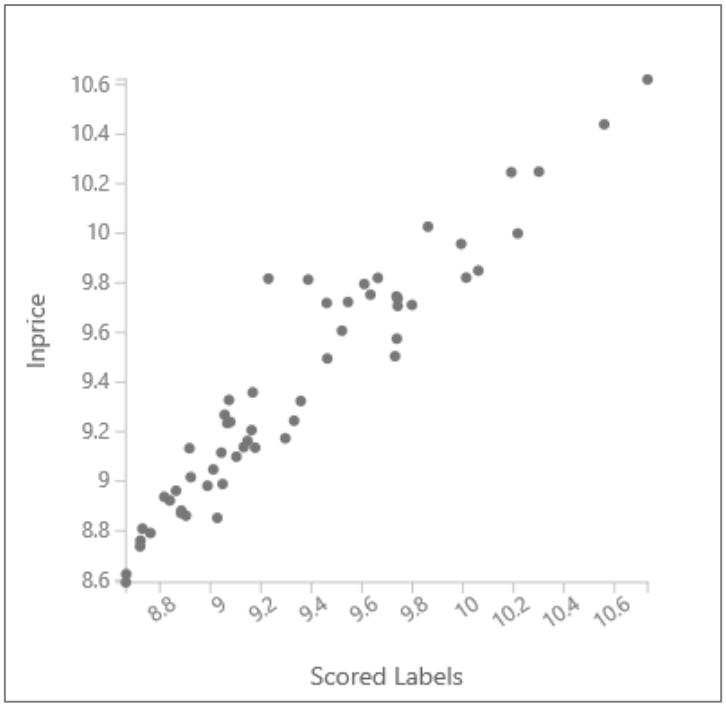
This translates in to the following standard performance metrics for classification:

- Accuracy: 95.5%
- Precision: 92.3%
- Recall: 100%
- F1 Score: 96%

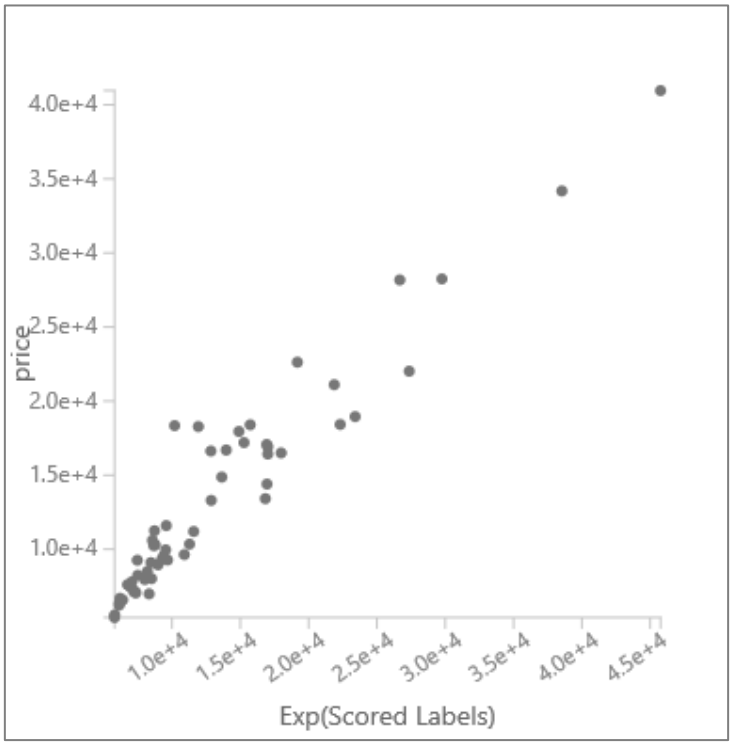
Regression

After creating a classification model to predict price categories, a regression model to predict the actual price of automobiles was created. Based on the apparent relationships identified when analyzing the data, a linear regression model was created to predict the log-normal value for price, from which the predicted price can be calculated.

The model was trained with 70% of the data, and tested with the remaining 30%. A scatter plot showing the predicted log prices and the actual log prices is shown below:



This plot shows a clear linear relationship between predicted and actual values in the test dataset. The Root Mean Square Error (RMSE) for the test results is 0.155637. Since the model predicts the log of price, and not the price itself, this figure does not represent the monetary amount by which the predicted value varies from the actual vale, but the standard deviation of log of price is 0.4993 – which is higher than the variance, indicating that the model performs reasonably well. When the predicted log price is converted back to its exponential value (the monetary price), the following scatter plot shows the results.



Conclusion

This analysis has shown that the price of an automobile can be confidently predicted from its characteristics. In particular, the manufacturer, number of cylinders, horsepower, city MPG, and drive wheels have a significant effect on the price of an automobile. Secondary features, such as fuel type can help further classify automobiles and determine price groupings to which they belong.