Automobile Performance Measurements

Applied Data Science and Analytics using Data

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Introduction and Overview

The automobile industry is fascinating, with so many makes, models, years, designs, performance, and a lot of other variables to take into account. There is a significant amount of personality that is associated with vehicles and everyone has different preferences. However, with increasing costs of fuel, we can all agree that regardless of driving a sports car, truck, SUV, or other type of vehicle that we would like to have higher fuel efficiency to reduce our total cost of ownership.

A shortlist of some of these automobile trends include:[1]

1. Electric vehicles (EV)
2. Self-driving technologies: using technologies such as radar, sonar, and lidar. Odometry measures detect environmental changes and maintaining safe speeds
3. Automotive cybersecurity: protecting digital systems inside a vehicle, while preventing hackers from gaining unauthorized access.
4. Connectivity & machine learning: emergency braking, entertainment, cyber security while connecting with devices such as smartphones and application services.
5. Improved safety features: emergency braking, blind-spot detection, land departure warnings, electronic stability control, adaptive cruise control
6. Insurance trends: insurers predicting risk using satellites and datasets.
7. Vehicle-to-vehicle communications: sharing information with other vehicles including location, speed, and direction.
8. Blockchain: sharing data in support of autonomous vehicles. Accessing traffic data to and payment tasks such as tolls, repairs, and insurance.
9. Environmental-friendly cars: vehicles built from recycled materials

As trends within the industry have moved from high performance vehicles to higher efficiency vehicles, this analysis using data science will include two sections. The initial section will analyze Motor Trends historic vehicle dataset which focuses on high performance factors. The next section of this analysis, which will be included within a subsequent analysis will utilize a dataset that is focused on efficiency. Many drivers value both both performance and efficiency.

The performance measures will explore a number of factors to better understand relationships within the data.

Load Programming Libraries

Load Data and review Summary Statistics

```
##       mpg             cyl             disp             hp             drat
##  Min.   :10.4   Min.   :4.00   Min.   : 71   Min.   : 52   Min.   :2.76
##  1st Qu.:15.4   1st Qu.:4.00   1st Qu.:121   1st Qu.: 96   1st Qu.:3.08
##  Median :19.2   Median :6.00   Median :196   Median :123   Median :3.69
##  Mean   :20.1   Mean   :6.19   Mean   :231   Mean   :147   Mean   :3.60
##  3rd Qu.:22.8   3rd Qu.:8.00   3rd Qu.:326   3rd Qu.:180   3rd Qu.:3.92
##  Max.   :33.9   Max.   :8.00   Max.   :472   Max.   :335   Max.   :4.93
##       wt             qsec            vs               am             gear
##  Min.   :1.51   Min.   :14.5   Min.   :0.000   Min.   :0.000   Min.   :3.00
##  1st Qu.:2.58   1st Qu.:16.9   1st Qu.:0.000   1st Qu.:0.000   1st Qu.:3.00
##  Median :3.33   Median :17.7   Median :0.000   Median :0.000   Median :4.00
##  Mean   :3.22   Mean   :17.9   Mean   :0.438   Mean   :0.406   Mean   :3.69
##  3rd Qu.:3.61   3rd Qu.:18.9   3rd Qu.:1.000   3rd Qu.:1.000   3rd Qu.:4.00
##  Max.   :5.42   Max.   :22.9   Max.   :1.000   Max.   :1.000   Max.   :5.00
##      carb
##  Min.   :1.00
##  1st Qu.:2.00
##  Median :2.00
##  Mean   :2.81
##  3rd Qu.:4.00
##  Max.   :8.00

## 'data.frame':    32 obs. of  11 variables:
##  $ mpg : num  21 21 22.8 21.4 18.7 18.1 14.3 24.4 22.8 19.2 ...
##  $ cyl : num  6 6 4 6 8 6 8 4 4 6 ...
##  $ disp: num  160 160 108 258 360 ...
##  $ hp  : num  110 110 93 110 175 105 245 62 95 123 ...
##  $ drat: num  3.9 3.9 3.85 3.08 3.15 2.76 3.21 3.69 3.92 3.92 ...
##  $ wt  : num  2.62 2.88 2.32 3.21 3.44 ...
##  $ qsec: num  16.5 17 18.6 19.4 17 ...
##  $ vs  : num  0 0 1 1 0 1 0 1 1 1 ...
##  $ am  : num  1 1 1 0 0 0 0 0 0 0 ...
##  $ gear: num  4 4 4 3 3 3 3 4 4 4 ...
##  $ carb: num  4 4 1 1 2 1 4 2 2 4 ...
```

Label Variables within the Dataframe to match the file descriptions using a Crosstable

```
# Assign new label names
df_labels = read.table(header = TRUE, text = "
  dataname  newname
  model 'MakeModel'
  mpg   'MPG'
  cyl   'Cylinders'
```

```
    disp  'Displacement'
    hp    'Gross horsepower'
    drat  'Rear axle ratio'
    wt    'Weight (1000 lbs)'
    qsec  '1/4 mile time in seconds'
    vs    'Engine'
    am    'Transmission'
    gear  'Number of Gears'
    carb  'Carburetors'
")

# New data frame
mtcarsCT = mtcars %>%
    mutate(model = rownames(mtcars), vs = ifelse(vs == 0, "vshaped", "straight"),
        am = ifelse(am == 0, "auto", "manual"), across(c("cyl", "gear"), factor),
        .before = 1) %>%
    import_labels(df_labels, name_from = "dataname", label_from = "newname")
# remove as_tibble()
```
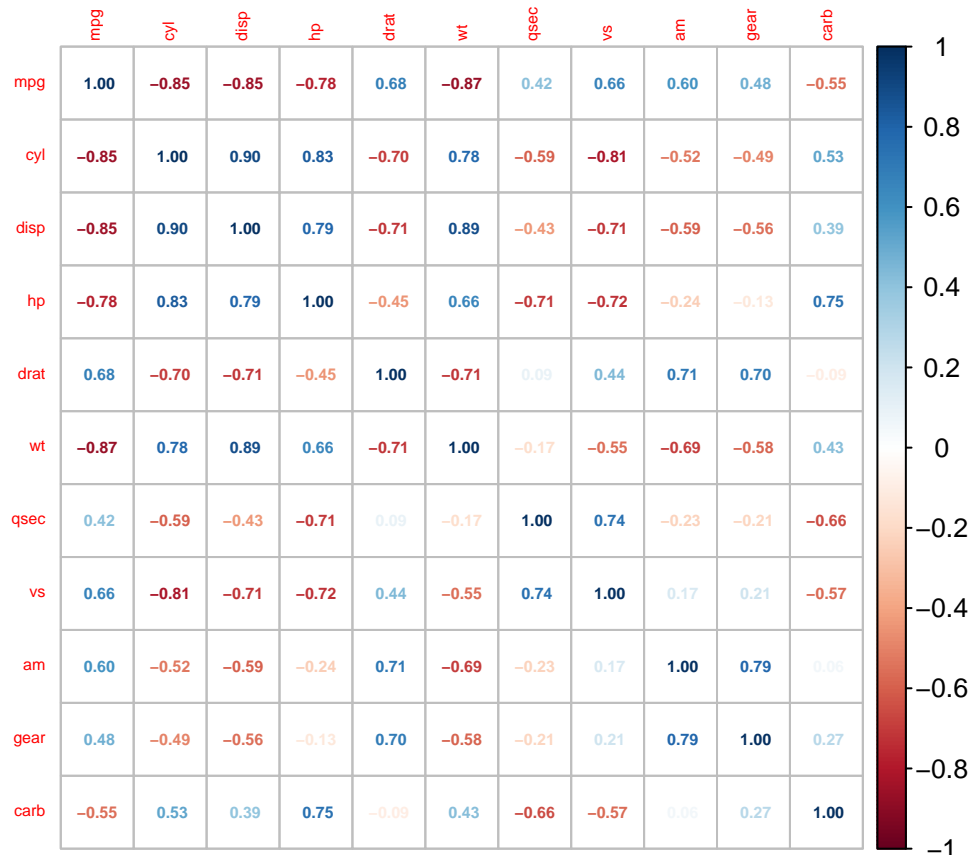
Vehicle Performance Characteristics

| .id | label | variable | Transmission | |
			auto	manual
cyl	Cylinders	4	3 (27.27%)	8 (72.73%)
		6	4 (57.14%)	3 (42.86%)
		8	12 (85.71%)	2 (14.29%)
hp	Gross horsepower	Min / Max	62.0 / 245.0	52.0 / 335.0
		Med [IQR]	175.0 [116.5;192.5]	109.0 [66.0;113.0]
		Mean (std)	160.3 (53.9)	126.8 (84.1)
		N (NA)	19 (0)	13 (0)
qsec	1/4 mile time in seconds	Min / Max	15.4 / 22.9	14.5 / 19.9
		Med [IQR]	17.8 [17.2;19.2]	17.0 [16.5;18.6]
		Mean (std)	18.2 (1.8)	17.4 (1.8)
		N (NA)	19 (0)	13 (0)
vs	Engine	straight	7 (50.00%)	7 (50.00%)
		vshaped	12 (66.67%)	6 (33.33%)

Data Correlation

Before we can make any assumptions within this data, let's see which variables had the strongest correlations with another using the Pearson Correlation Coefficient.

	mpg	cyl	disp	hp	drat	wt	qsec	vs	am	gear	carb
mpg	1.00	−0.85	−0.85	−0.78	0.68	−0.87	0.42	0.66	0.60	0.48	−0.55
cyl	−0.85	1.00	0.90	0.83	−0.70	0.78	−0.59	−0.81	−0.52	−0.49	0.53
disp	−0.85	0.90	1.00	0.79	−0.71	0.89	−0.43	−0.71	−0.59	−0.56	0.39
hp	−0.78	0.83	0.79	1.00	−0.45	0.66	−0.71	−0.72	−0.24	−0.13	0.75
drat	0.68	−0.70	−0.71	−0.45	1.00	−0.71	0.09	0.44	0.71	0.70	−0.09
wt	−0.87	0.78	0.89	0.66	−0.71	1.00	−0.17	−0.55	−0.69	−0.58	0.43
qsec	0.42	−0.59	−0.43	−0.71	0.09	−0.17	1.00	0.74	−0.23	−0.21	−0.66
vs	0.66	−0.81	−0.71	−0.72	0.44	−0.55	0.74	1.00	0.17	0.21	−0.57
am	0.60	−0.52	−0.59	−0.24	0.71	−0.69	−0.23	0.17	1.00	0.79	0.06
gear	0.48	−0.49	−0.56	−0.13	0.70	−0.58	−0.21	0.21	0.79	1.00	0.27
carb	−0.55	0.53	0.39	0.75	−0.09	0.43	−0.66	−0.57	0.06	0.27	1.00

This data reveals strong correlations above 0.60 (between -1 and +1) include:

- Miles per Gallon: Rear axle ratio, Engine, Transmission,
- Cylinders: displacement, horsepower, weight
- Displacement: Cylinders
- Gross horsepower: Cylinders, Displacement, Carburetors
- Rear axle ratio: Transmission, Number of Gears
- Weight (1000 lbs): Cylinders, Displacement, Gross horsepower
- 1/4 mile time in seconds: Engine
- Engine: Transmission
- Transmission: Number of Gears
- Number of Gears: Gross horsepower, Transmission, Number of Gears
- Carburetors: Gross horsepower

Many of these variables seem very sensible, such as miles per gallon being related to the engine and transmission size, relationships of engines and transmissions, or transmissions and the number of gears.

Principal Component Analysis (PCA)

Principal component analysis (PCA) provides the ability to understand the structure of the data, similarity/differences, while determining which variables have the a higher level of variance. Eigenvalues and eigenvectors provide the ability to determine how much variance exists in data going in a certain direction, and vectors with the highest eigenvalue are the first principal component. We previously visualized the correlations, now let's take a look at the principal compoenent analysis to visualize the similarity and differences of these factors.

```
## Standard deviations (1, .., p=11):
##  [1] 2.571 1.628 0.792 0.519 0.473 0.460 0.368 0.351 0.278 0.228 0.148
##
## Rotation (n x k) = (11 x 11):
##          PC1     PC2     PC3      PC4     PC5     PC6     PC7      PC8      PC9
## mpg  -0.363  0.0161 -0.2257 -0.02254  0.1028 -0.1088  0.3677 -0.75409  0.23570
## cyl   0.374  0.0437 -0.1753 -0.00259  0.0585  0.1686  0.0573 -0.23082  0.05404
## disp  0.368 -0.0493 -0.0615  0.25661  0.3940 -0.3362  0.2143  0.00114  0.19843
## hp    0.330  0.2488  0.1400 -0.06768  0.5400  0.0714 -0.0015 -0.22236 -0.57583
## drat -0.294  0.2747  0.1612  0.85483  0.0773  0.2445  0.0211  0.03219 -0.04690
## wt    0.346 -0.1430  0.3418  0.24590 -0.0750 -0.4649 -0.0207 -0.00857  0.35950
## qsec -0.200 -0.4634  0.4032  0.06808 -0.1647 -0.3305  0.0500 -0.23184 -0.52838
## vs   -0.307 -0.2316  0.4288 -0.21485  0.5995  0.1940 -0.2658  0.02594  0.35858
## am   -0.235  0.4294 -0.2058 -0.03046  0.0898 -0.5708 -0.5873 -0.05975 -0.04740
## gear -0.207  0.4623  0.2898 -0.26469  0.0483 -0.2436  0.6051  0.33615 -0.00174
## carb  0.214  0.4136  0.5285 -0.12679 -0.3613  0.1835 -0.1746 -0.39563  0.17064
##          PC10     PC11
## mpg   0.1393 -0.12490
## cyl  -0.8464 -0.14070
## disp  0.0494  0.66061
## hp    0.2478 -0.25649
## drat -0.1015 -0.03953
## wt    0.0944 -0.56745
## qsec -0.2707  0.18136
## vs   -0.1590  0.00841
## am   -0.1778  0.02982
## gear -0.2138 -0.05351
## carb  0.0723  0.31959
```

Variables – PCA
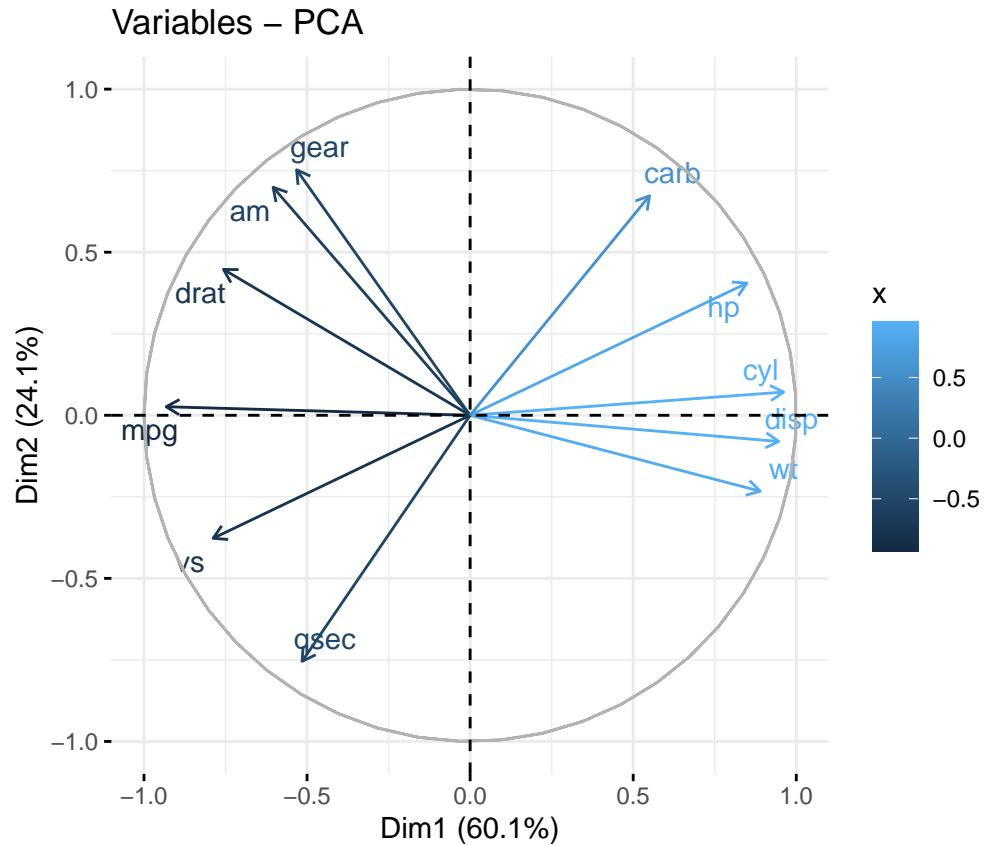
PCA Visualization

The PCA relationships are important to understand and the relationships show similarities to the previous correlation values. We may have considered that miles per gallon were related to the weight of the car, however there is a much higher relationship to the engine size. The horsepower has a much higher relationship to the amount of cylinders, carburetors, and displacement.

This analysis also helps us to understand that the fastest quarter mile depends upon the size of the engine, as it is the nearest dimensional PCA.

Now, let's see which vehicles within this dataset performed the fastest on a quarter mile.

Performance Quarter Mile
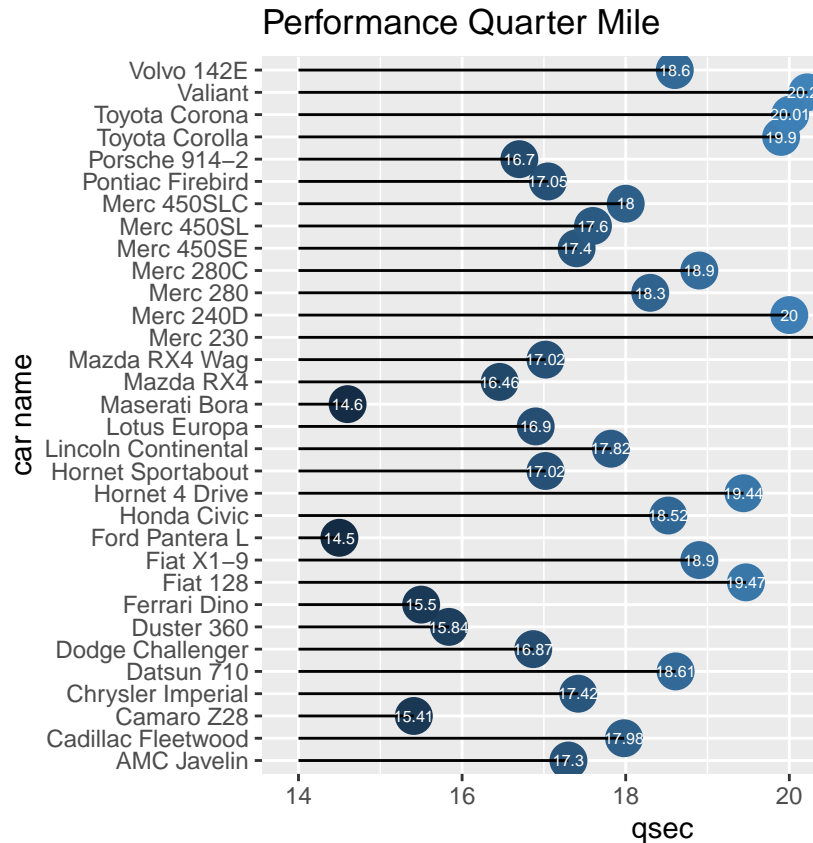
Fastest Vehicles on the Quarter Mile Tests

This dot plot provides a great visualization to see which makes and models of vehicles were performing the most effectively in quarter mile tests. The fastest four vehicles in this dataset include the Ford, followed by the Maserati, Camero, and Ferrari.

The final segment of this analysis will include analyzing which vehicles performed the most effectively for fuel consumption, and will also leave us to analyze the second portion of this analysis on vehicles.

Diverging Bars

Normalised mileage from 'mtcars'
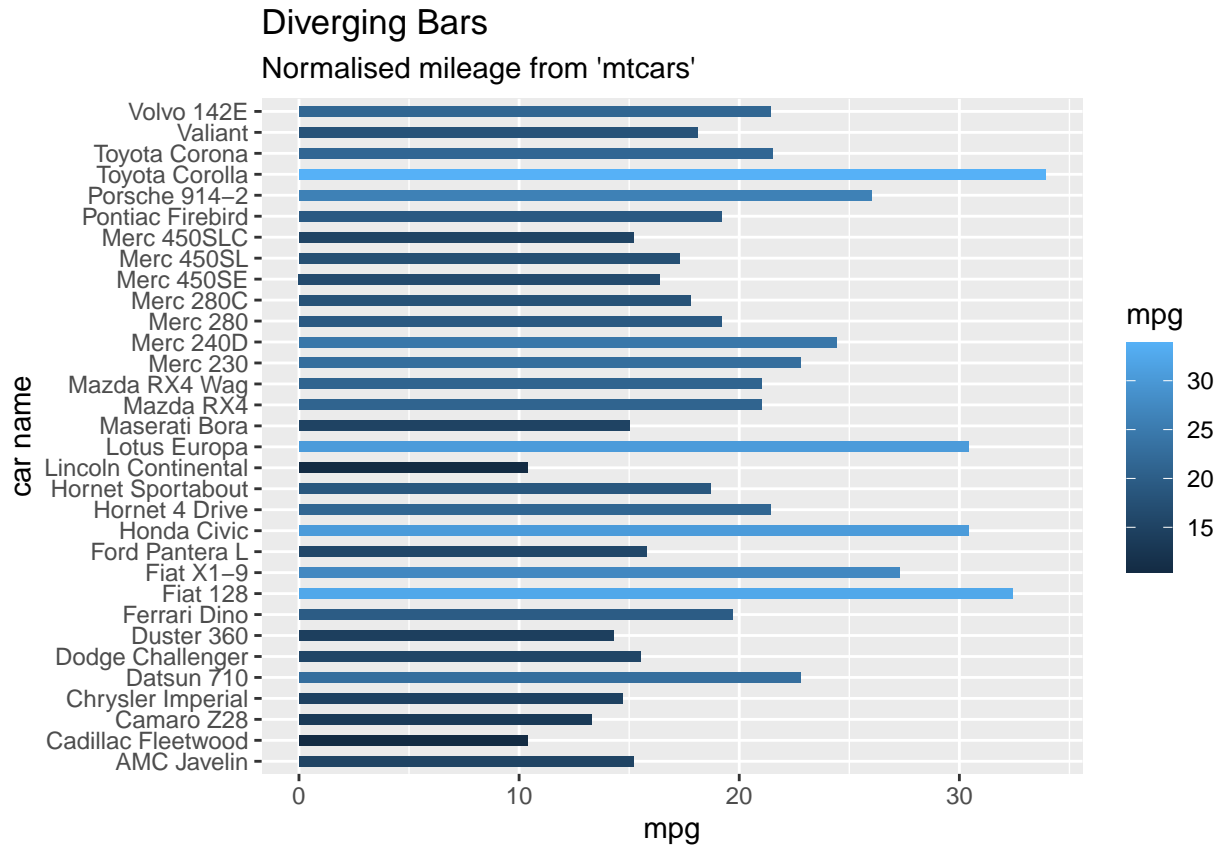
In this analysis for fuel efficiency, we can see that the Toyota, Fiat, followed by the Honda and Lotus vehicles were the most efficient.

Further Analysis

This sort-segment of analysis using the built-in Motor Trends dataset was very effective for scaling this type of analysis on updated datasets. Please continue to follow Rpubs, GitHub, and other sources for future analysis.

References and Works Cited

1. Sampson, "9 Automotive Trends For 2022", Auto Trends Magazine, 2022. [Online]. Available: https://autotrends.org/automotive-trends-2022/.
2. "Motor Trend Car Road Tests", R-Project. [online] Available: https://search.r-project.org/R/refmans/datasets/html/mtcars.html

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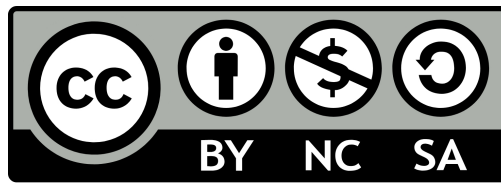
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