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CSCI 347 Project 1: Exploratory Data Analysis

The Automobile Data Set is a multivariate dataset with 26 attributes and 205 entities that is commonly used for regression. The data was used for analysing risk ratings of cars in terms of insurance based on the price and many characteristics. It was created/donated by Jeffrey C. Schlimmer. There are 16 numerical attributes and 10 categorical attributes. Most of the categorical attributes can be one-hot-encoded, except for the attribute 'num-of-cylinders', which has a specific order. There are missing values in the data. Approximately 1% of the data overall is missing.

Attribute:	Number of instances missing a value:
normalized losses	41
number of doors	2
bore	4
stroke	4
horsepower	2
peak rpm	2
price	4

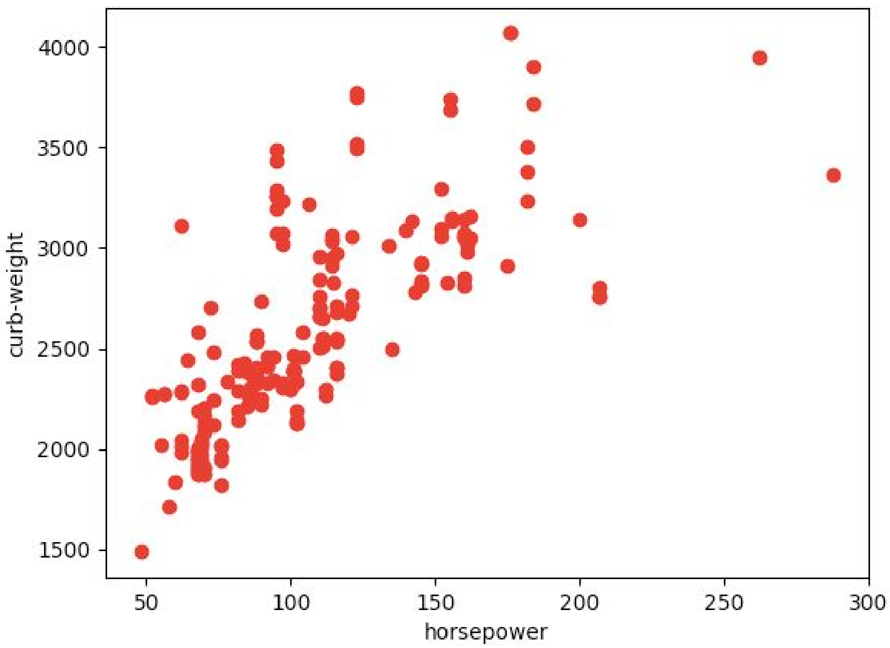
This data set is interesting to us because it combines numerical and categorical attributes, it has a lot of attributes, and it seems like an interesting subject. The attributes that we think will be the most descriptive of the data are the horsepower and price attributes, because we are trying to look at the relationship between a car's characteristics and its insurance risk. A more powerful car and expensive car might be seen as more of a risk.

Data Analysis

The multivariate mean and covariance matrices will be included as CSV files. After one-hot-encoding, the attribute number increased to 76, which makes displaying the data in this report cumbersome.

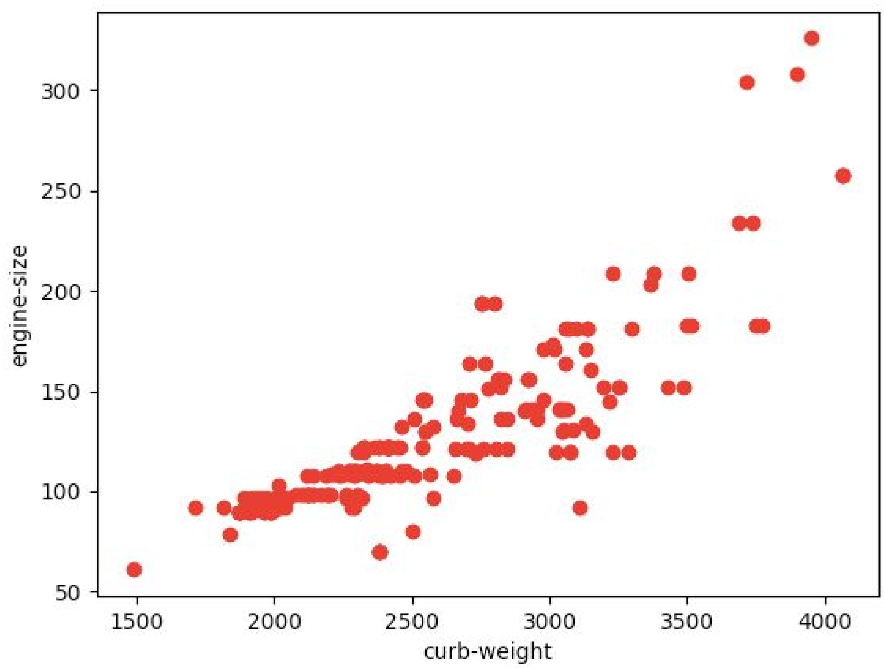
Here are the 5 pairs of attributes we thought might be related:

Curb Weight and Horsepower



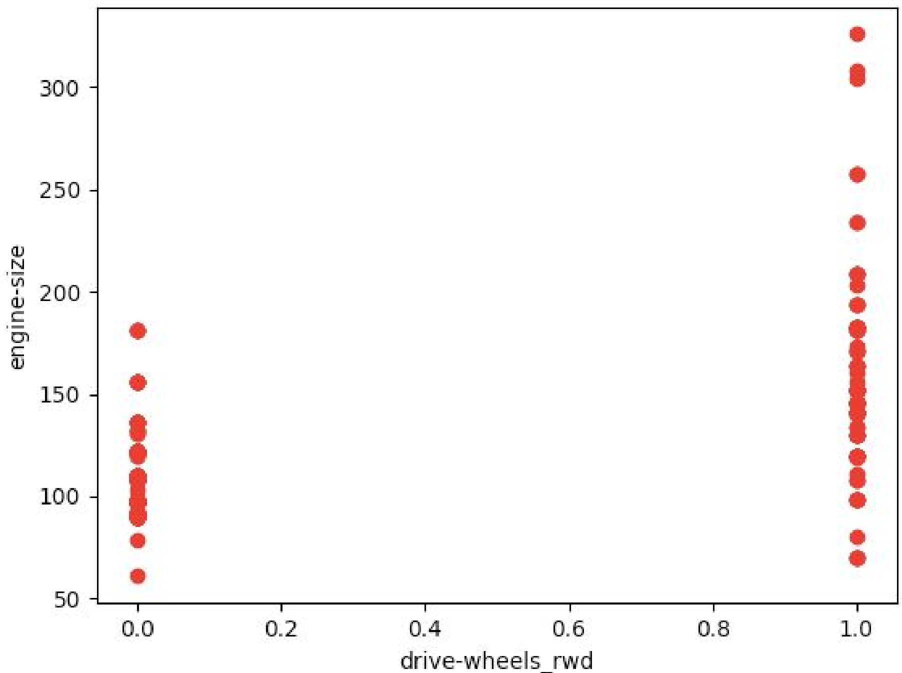
This plot shows that as horsepower increases, so does curb weight. This pair might be related because the heavier the car is, the more horsepower it will need to move the car. The scatterplot supports this intuition.

Engine Size and Curb Weight



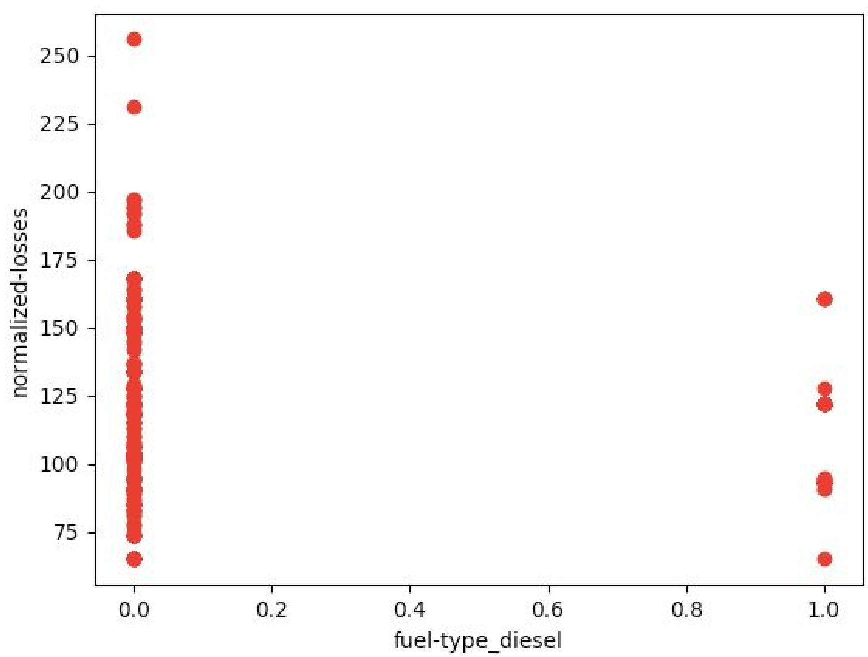
The above plot shows the relationship between engine size and curb weight. If a car has a larger engine, it most likely will weigh more overall. The scatterplot supports this intuition.

Engine Size and Rear Wheel Drive



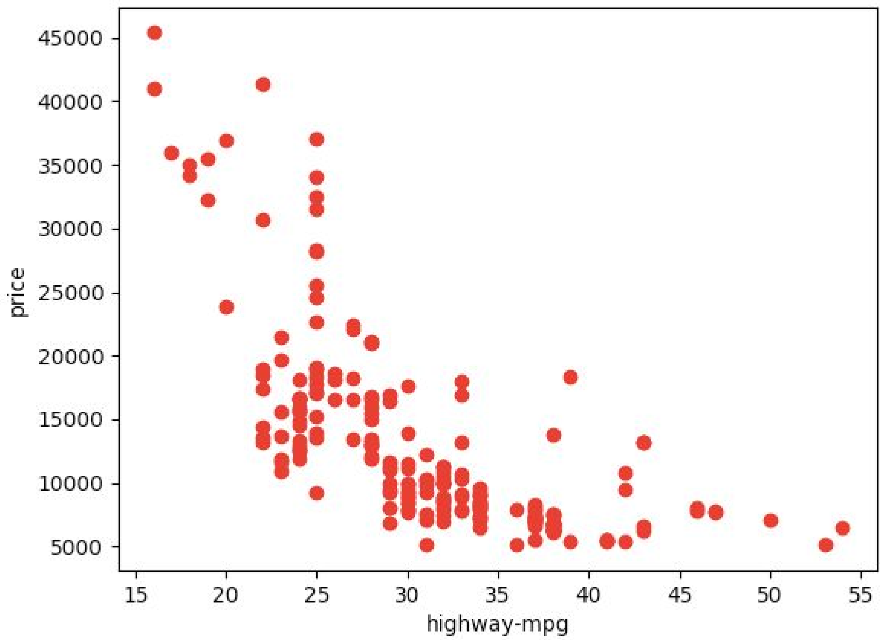
The above plot shows the relationship between engine size and whether a car is rwd or not. This shows that although rear wheel drive is seen across all engine sizes, the cars with the largest engines are rear wheel drive. This makes sense, as large sports cars and trucks are mainly rear wheel drive. The scatterplot supports this intuition.

Normalized Losses and Diesel



The above plot shows the relationship between normalized losses and diesel cars. The cars with the highest loss are not diesel. This was against our intuition, as we assumed diesel cars would have a higher loss in terms of insurance investment. The scatterplot did not support our intuition.

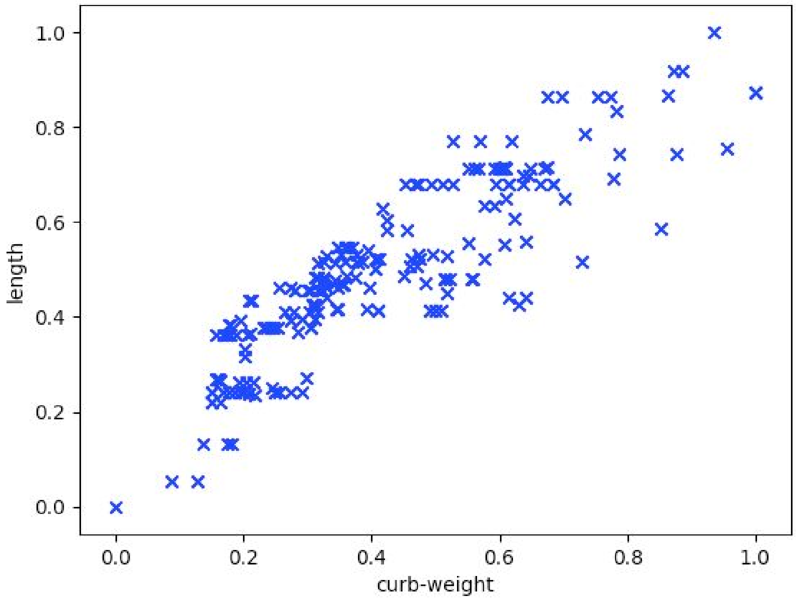
Price and Highway MPG



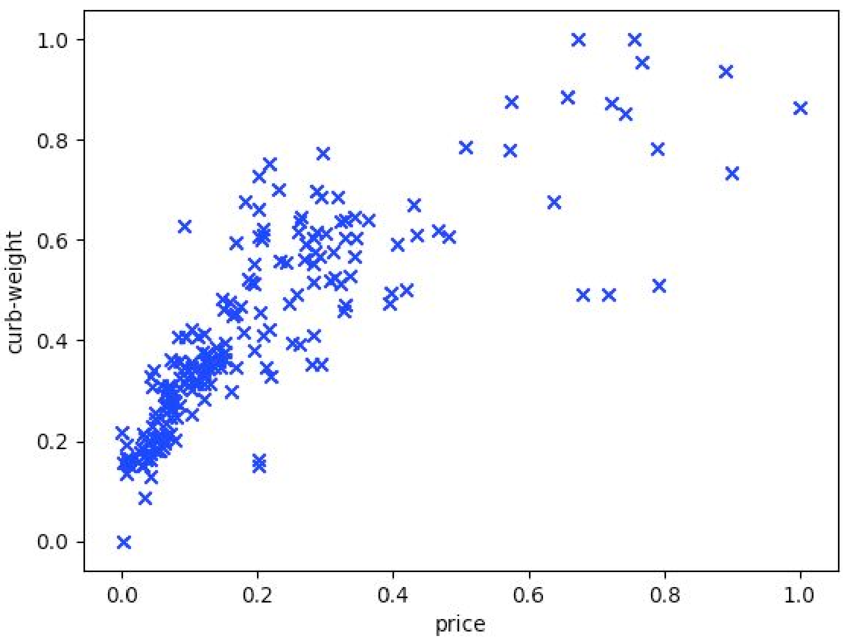
This last plot shows the relationship between price and highway mpg. Cheaper cars are likely to have small, efficient engines. If someone can afford a more expensive car, they can probably afford to pay more in gas as well. The scatterplot supports this intuition.

Range Normalized Numerical Attributes with the Greatest Sample Covariance

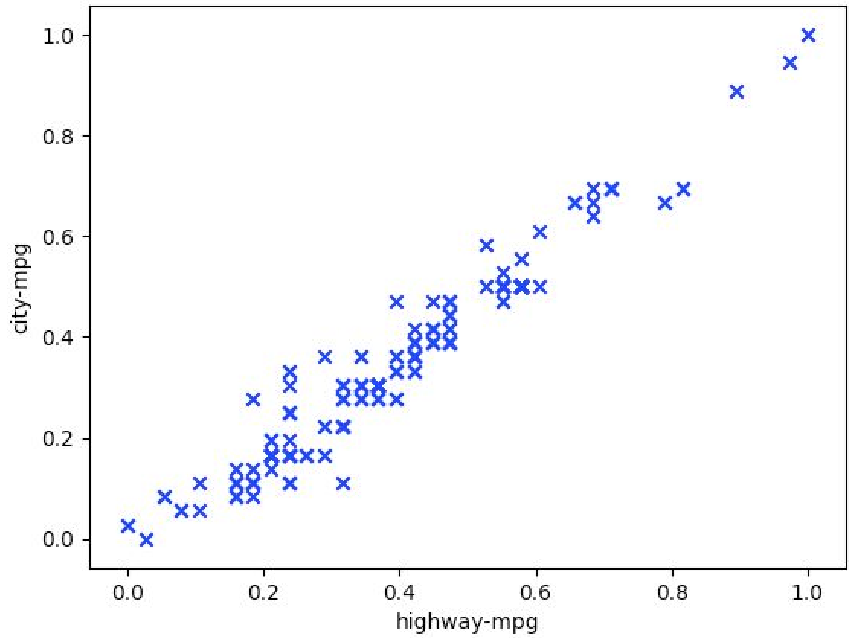
1. Curb Weight and Length with a sample covariance of 0.0326



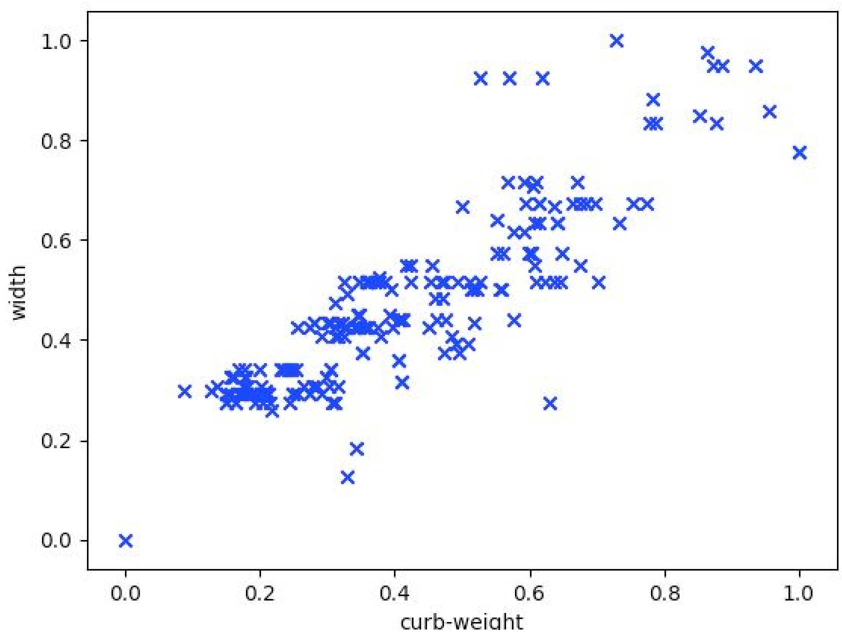
2. Price and Curb Weight with a sample covariance of 0.0324



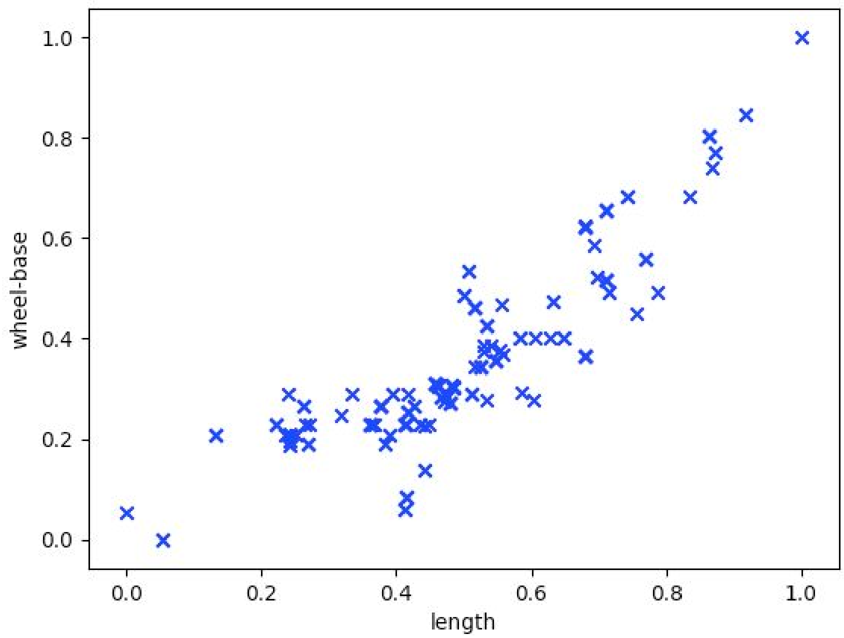
3. Highway MPG and City MPG with a sample covariance of 0.0320



4. Curb Weight and Width with a sample covariance of 0.0313

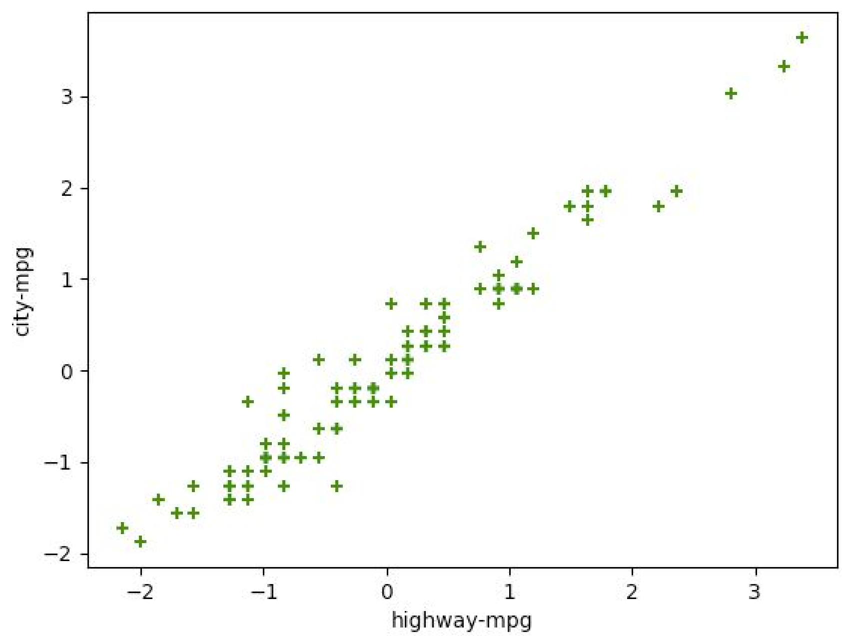


5. Length and Wheelbase with a sample covariance of 0.0283

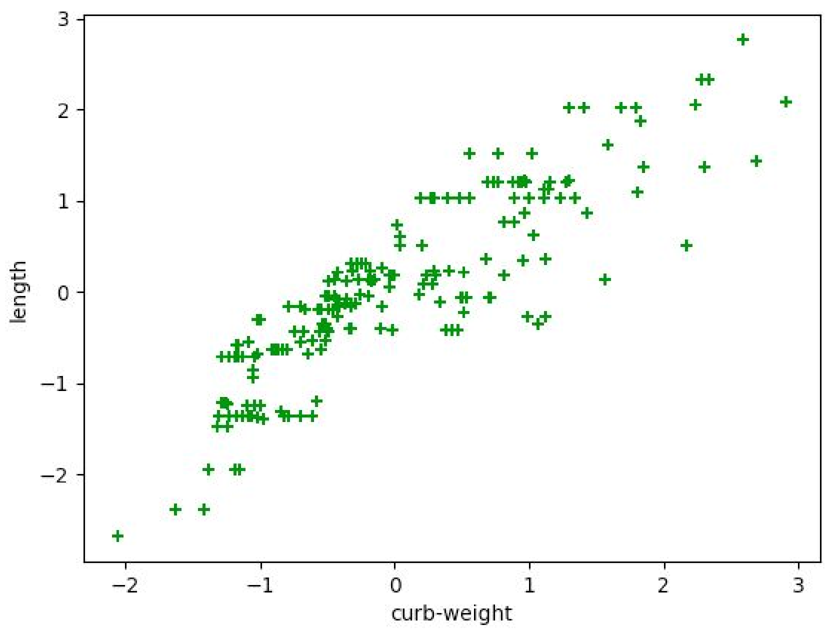


Standard Normalized Numerical Attributes with the Greatest Correlation

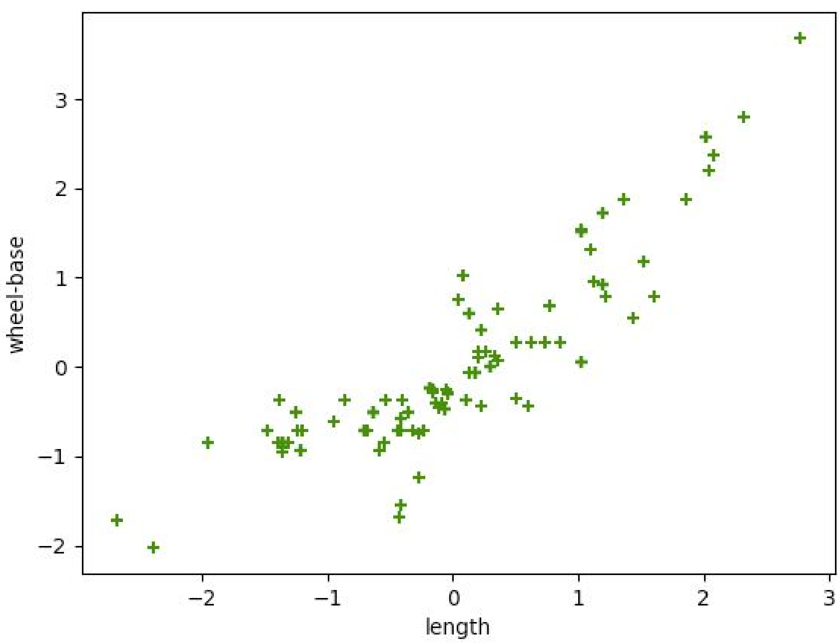
1. Highway MPG and City MPG with a correlation of 0.9713



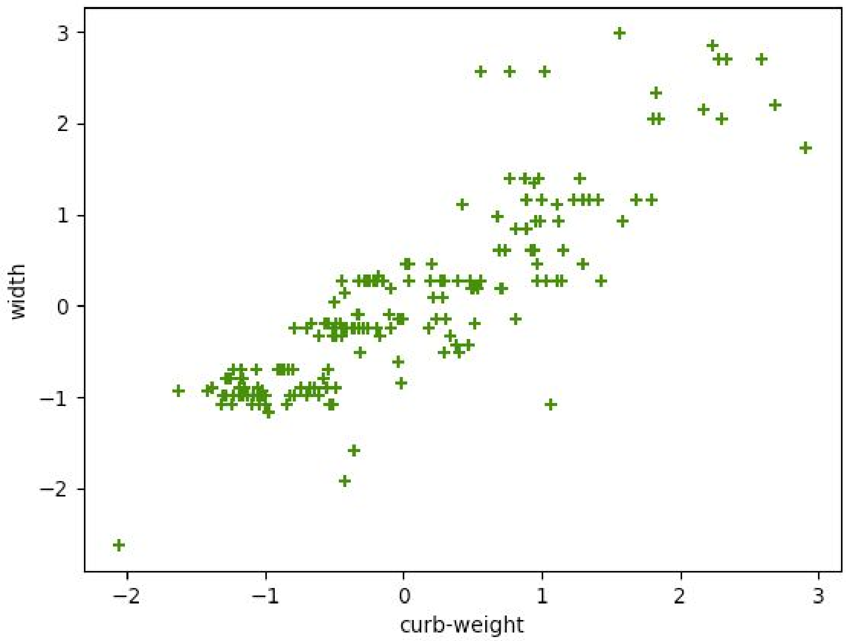
2. Curb Weight and Length with a correlation of 0.8777



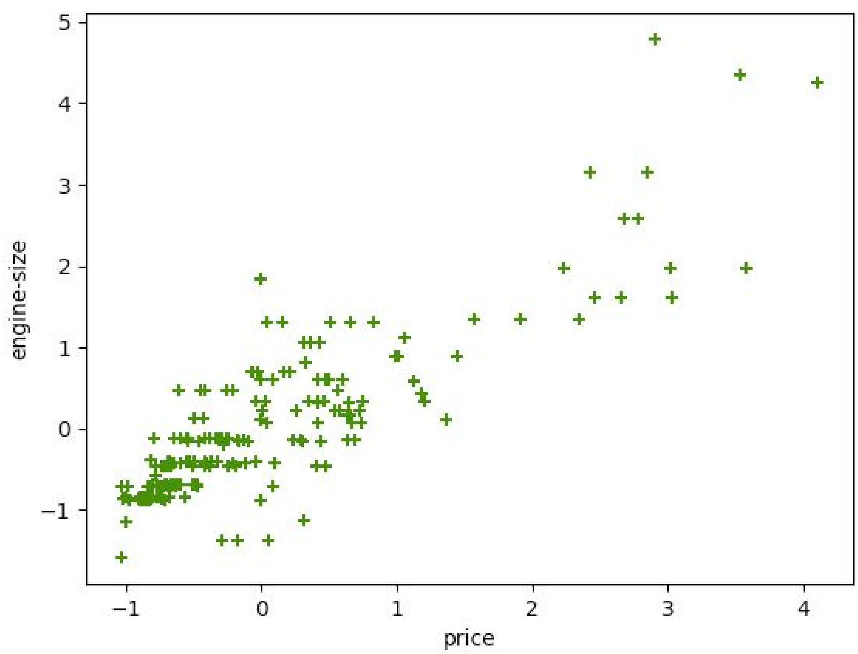
3. Length and Wheelbase with a correlation of 0.8746



4. Curb Weight and Width with a correlation of 0.8670

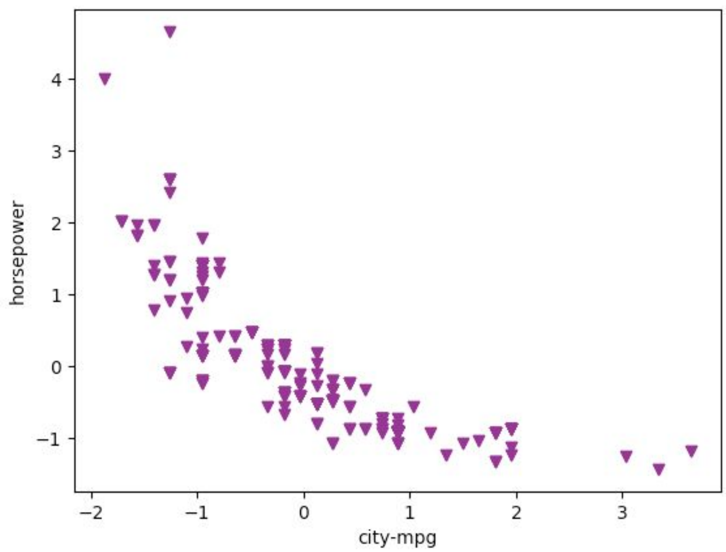


5. Price and Engine Size with a correlation of 0.8616

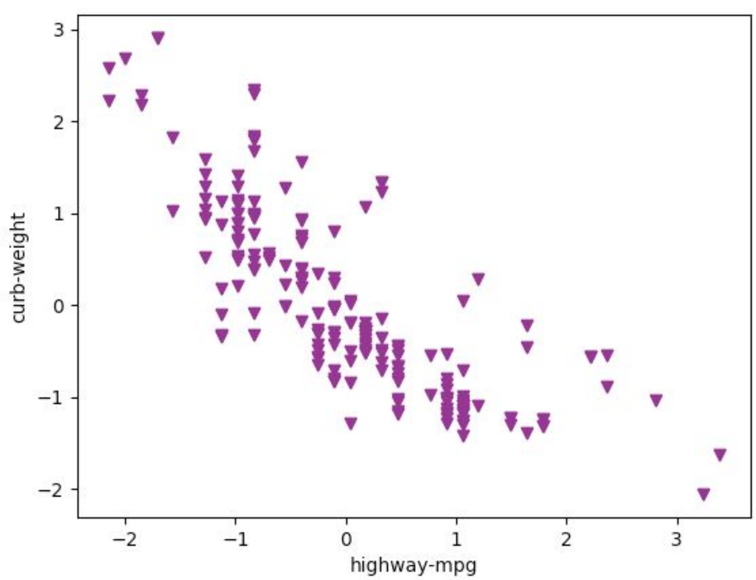


<u>Standard Normalized Numerical Attributes with the Least Correlation</u>

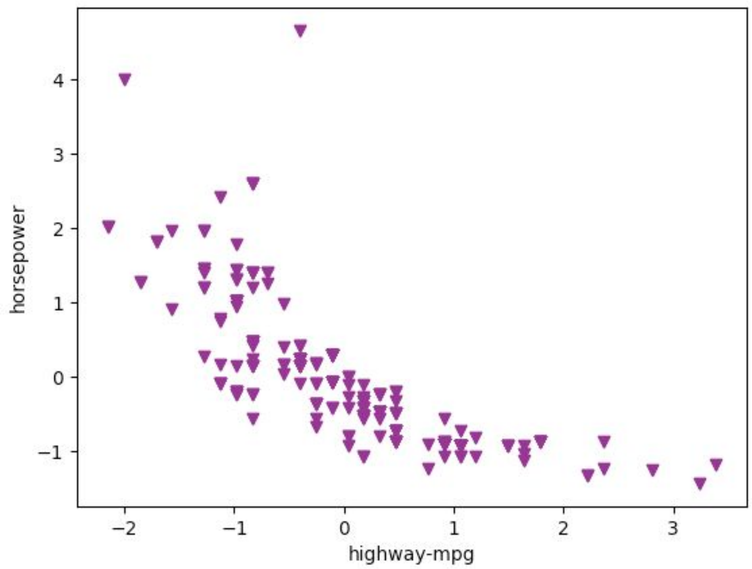
1. City MPG and Horsepower with a correlation of -0.8032



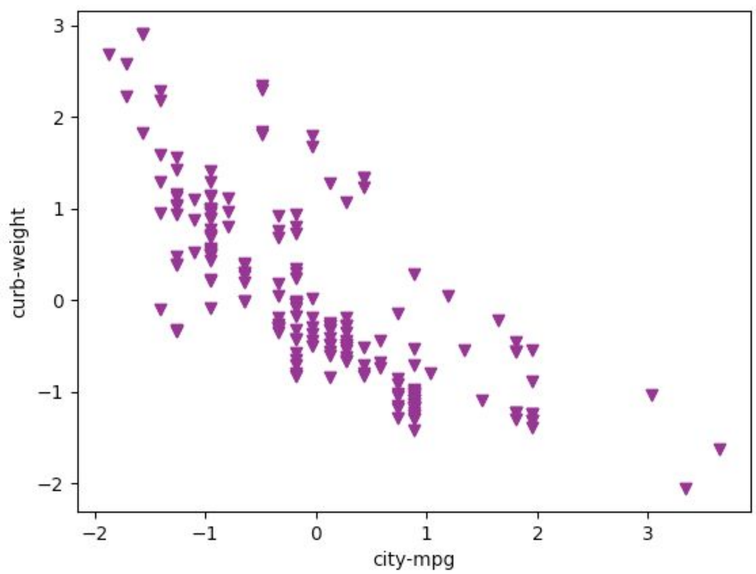
2. Highway MPG and Curb Weight with a correlation of -0.7975



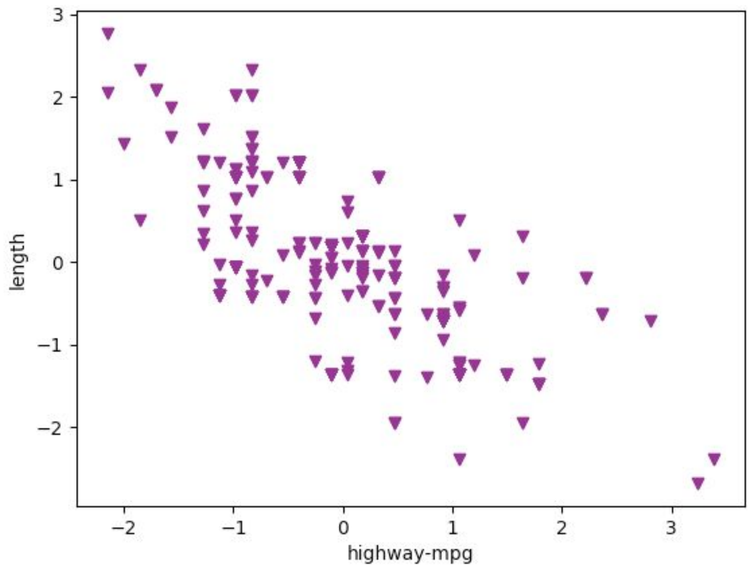
3. Highway MPG and Horsepower with a correlation of -0.7709



4. City MPG and Curb Weight with a correlation of -0.7574



5. Highway MPG and Length with a correlation of -0.7047



There are 106 pairs of features with a correlation greater than or equal to 0.5.
There are 1854 pairs of features with a negative sample covariance.
The total variance of the data is 62420741.1.
The total variance restricted to the five features with the greatest sample variance is 62419426.

```python
'''
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CSCI 347 Project 1
Python Code for Data Analysis
'''
import numpy as np
import pandas as pd
import math
from numpy import genfromtxt
from sklearn.impute import SimpleImputer
from sklearn.preprocessing import MinMaxScaler
import matplotlib.pyplot as plt

'''
A function to compute the mean of a numerical, multidimensional data set
input as a 2-dimensional numpy array
'''
def computeMean(arr):
    mean = np.zeros(arr.shape[1])
    for a in arr:
        mean += a
    mean = mean / arr.shape[0]
    return mean

'''
A function to compute the sample covariance between two attributes that
are input as one-dimensional numpy vectors
'''
def computeCovar(v1, v2):
    v1mean = np.mean(v1)
    v2mean = np.mean(v2)
    n = np.size(v1)

    summ = 0

    for i in range(n):
        summ += (v1[i]-v1mean)*(v2[i]-v2mean)

    cov = summ/(n-1)

    return cov

'''
A function to compute the correlation between two attributes that are input as
one-dimensional numpy vectors
'''
```

```
def computeCorr(v1, v2):
   cov12 = computeCovar(v1,v2)
   cov1 = computeCovar(v1,v1)
   cov2 = computeCovar(v2,v2)

   corr = cov12/math.sqrt(cov1*cov2)
   return corr

'''
A function to range normalize a two-dimensional numpy array
'''
def rangeNorm(arr):
   normArr = arr
   minimum = np.amin(normArr, axis=0)
   maximum = np.amax(normArr, axis=0)

   normArr = normArr.astype('float32')

   for col in range(len(normArr)):
     for row in range(len(normArr[col,:])):
        normArr[col][row] = (normArr[col][row]-minimum[row])/(maximum[row]-
minimum[row])
   return normArr

'''
A function to standard normalize a two-dimensional numpy array
'''
def standardNorm(arr):
   normArr = arr
   std = np.std(normArr, axis=0)
   mean = computeMean(normArr)

   normArr = normArr.astype('float32')

   for col in range(len(normArr)):
     for row in range(len(normArr[col,:])):
        normArr[col][row] = (normArr[col][row]-mean[row])/(std[row])
   return normArr

'''
A function to compute the covariance matrix of a dataset
'''
def computeCovarMatrix(arr):
   n = arr.shape[1]
   covarMatrix = np.zeros([n,n], dtype = float)
   for col in range(n):
      for row in range(n):
```

```
            covarMatrix[col][row] = computeCovar(arr[:,col],arr[:,row])

    return covarMatrix

'''
A function to label-encode categorical data
'''
def labelEncode(v):
    encodedV = np.zeros(len(v), dtype = float)
    stringlist = []
    for i in range(len(v)):
        d = v[i].strip()
        if (d not in stringlist):
            stringlist.append(d)
            d = len(stringlist)
        else:
            d = stringlist.index(d)
        encodedV[i] = float(d)
    if (len(stringlist) > 0):
        print("Removed Strings")
    return encodedV

# A function to make a correlation matrix
def computeCorrMatrix(arr):
    n = arr.shape[1]
    corrMatrix = np.zeros([n,n], dtype = float)
    for col in range(n):
        for row in range(n):
            corrMatrix[col][row] = computeCorr(arr[:,col],arr[:,row])

    return corrMatrix

#Tests all the python functions written for Part 2
def testFunc():
    a = np.array([[7,14,33,48,-1],[5,15,34,50,0],[8,17,32,41,1]])
    b = np.array(["x-large","medium","large","medium","small"])
    v1 = np.array([1,2,3,2,4,1,2,1,1])
    v2 = np.array([4,1,3,1,1,0,2,1,3])

    #The equivalent solution with libraries is commented out

    print("Testing compute mean")
    print(computeMean(a))
##    print(np.mean(a, axis=0))
    print("Testing compute covariance")
    print(computeCovar(v1,v2))
##    print(np.cov(v1,v2)[1][0])
```

```
    print("Testing compute correlation")
    print(computeCorr(v1,v2))
##    print(np.corrcoef(v1,v2))
    print("Testing range normalization")
    print(rangeNorm(a))
##    scaler = MinMaxScaler()
##    scaler.fit(a)
##    print(scaler.transform(a))
    print("Testing standard normalization")
    print(standardNorm(a))
    print("Testing compute covariance matrix")
    print(computeCovarMatrix(a))
##    print(np.cov(a.transpose()))
    print("Testing label encoding")
    print(labelEncode(b))


#Driver for Part 3
def main():
    print("Reading input from file")
    df = pd.read_csv('https://archive.ics.uci.edu/ml/machine-learning-databases/autos/
imports-85.data',header=None,names=columns, na_values=['?'])

    #One-hot-encoding all categorical data
    df = pd.get_dummies(df, columns=categorical)

    for i in range(len(df.columns)):
        df.iloc[:, i].fillna(df.iloc[:, i].mean(), inplace=True)

    arr = df.to_numpy()
    colNames = list(df.columns.values)

    #This code generates the multivariate mean and covar matrix
    #and writes the output to a csv
    #commented out to simplify things

    #multivariate mean
    multMean = computeMean(arr)
    f = open("q1.csv", "w")
    for a in range(len(multMean)):
        f.write("{},{}\n".format(colNames[a],multMean[a]))
    f.close()

    #covariance matrix
    matrix = computeCovarMatrix(arr)
    f = open("covarMatrix.csv", "w")
    for i in range(matrix.shape[0]):
```

```
    for j in range(matrix.shape[1]):
        f.write("{}".format(matrix[i][j]))
        if (j != matrix.shape[1]-1):
            f.write(",")
        else:
            f.write("\n")
f.close()
#correlation matrix
matrix = computeCorrMatrix(arr)
f = open("corrMatrix.csv", "w")
for i in range(matrix.shape[0]):
    for j in range(matrix.shape[1]):
        f.write("{}".format(matrix[i][j]))
        if (j != matrix.shape[1]-1):
            f.write(",")
        else:
            f.write("\n")
f.close()

#total variance
matrix = computeCovarMatrix(arr)
totalVar = 0
for i in range(matrix.shape[0]):
    for j in range(matrix.shape[1]):
        if i == j:
            totalVar += matrix[i][j]
print(totalVar)

matrix = computeCovarMatrix(arr)
f = open("sampleCovarMatrix.csv", "w")
for i in range(matrix.shape[0]):
    for j in range(matrix.shape[1]):
        if j == i:
            f.write("{}".format(matrix[i][j]))
        else:
            f.write("0")
        if (j != matrix.shape[1]-1):
            f.write(",")
        else:
            f.write("\n")
f.close()

#select attributes to plot
#commented out to simplify things

plt.figure(1)
plt.scatter(arr[:, 38], arr[:, 1], color = 'red', marker = 'o')
```

```
plt.xlabel(colNames[38])
plt.ylabel(colNames[1])

plt.figure(2)
plt.scatter(arr[:, 11], arr[:, 6], color = 'red', marker = 'o')
plt.xlabel(colNames[11])
plt.ylabel(colNames[6])

plt.figure(3)
plt.scatter(arr[:, 6], arr[:, 7], color = 'red', marker = 'o')
plt.xlabel(colNames[6])
plt.ylabel(colNames[7])

plt.figure(4)
plt.scatter(arr[:, 51], arr[:, 7], color = 'red', marker = 'o')
plt.xlabel(colNames[51])
plt.ylabel(colNames[7])

plt.figure(5)
plt.scatter(arr[:, 14], arr[:, 15], color = 'red', marker = 'o')
plt.xlabel(colNames[14])
plt.ylabel(colNames[15])

plt.show()


#range normalize the numerical data

norm = rangeNorm(arr)

normMatrix = computeCovarMatrix(norm)
f = open("q3.csv", "w")
for i in range(16):
    for j in range(16):
        if j != i:
            f.write("{}".format(normMatrix[i][j]))
        else:
            f.write("0")
        if (j != 15):
            f.write(",")
        else:
            f.write("\n")
f.close()

#plot the normalized attribute pairs with the highest covariance
plt.figure(1)
plt.scatter(norm[:, 6], norm[:, 3], color = 'blue', marker = 'x')
```

```
plt.xlabel(colNames[6])
plt.ylabel(colNames[3])

plt.figure(2)
plt.scatter(norm[:, 15], norm[:, 6], color = 'blue', marker = 'x')
plt.xlabel(colNames[15])
plt.ylabel(colNames[6])

plt.figure(3)
plt.scatter(norm[:, 14], norm[:, 13], color = 'blue', marker = 'x')
plt.xlabel(colNames[14])
plt.ylabel(colNames[13])

plt.figure(4)
plt.scatter(norm[:, 6], norm[:, 4], color = 'blue', marker = 'x')
plt.xlabel(colNames[6])
plt.ylabel(colNames[4])

plt.figure(5)
plt.scatter(norm[:, 3], norm[:, 2], color = 'blue', marker = 'x')
plt.xlabel(colNames[3])
plt.ylabel(colNames[2])

plt.show()


#Take the standard norm and find the correlation for numerical attributes
norm = standardNorm(arr)

normMatrix = computeCorrMatrix(norm)
f = open("q4.csv", "w")
for i in range(16):
    for j in range(16):
        if j != i:
            f.write("{}".format(normMatrix[i][j]))
        else:
            f.write("0")
        if (j != 15):
            f.write(",")
        else:
            f.write("\n")
f.close()


#These plots are for greatest correlation
plt.figure(1)
plt.scatter(norm[:, 14], norm[:, 13], color = 'green', marker = '+')
```

```
plt.xlabel(colNames[14])
plt.ylabel(colNames[13])

plt.figure(2)
plt.scatter(norm[:, 6], norm[:, 3], color = 'green', marker = '+')
plt.xlabel(colNames[6])
plt.ylabel(colNames[3])

plt.figure(3)
plt.scatter(norm[:, 3], norm[:, 2], color = 'green', marker = '+')
plt.xlabel(colNames[3])
plt.ylabel(colNames[2])

plt.figure(4)
plt.scatter(norm[:, 6], norm[:, 4], color = 'green', marker = '+')
plt.xlabel(colNames[6])
plt.ylabel(colNames[4])

plt.figure(5)
plt.scatter(norm[:, 15], norm[:, 7], color = 'green', marker = '+')
plt.xlabel(colNames[15])
plt.ylabel(colNames[7])

plt.show()


#These plots are for least correlation
plt.figure(1)
plt.scatter(norm[:, 13], norm[:, 11], color = 'purple', marker = 'v')
plt.xlabel(colNames[13])
plt.ylabel(colNames[11])

plt.figure(2)
plt.scatter(norm[:, 14], norm[:, 6], color = 'purple', marker = 'v')
plt.xlabel(colNames[14])
plt.ylabel(colNames[6])

plt.figure(3)
plt.scatter(norm[:, 14], norm[:, 11], color = 'purple', marker = 'v')
plt.xlabel(colNames[14])
plt.ylabel(colNames[11])

plt.figure(4)
plt.scatter(norm[:, 13], norm[:, 6], color = 'purple', marker = 'v')
plt.xlabel(colNames[13])
plt.ylabel(colNames[6])
```

```
    plt.figure(5)
    plt.scatter(norm[:, 14], norm[:, 3], color = 'purple', marker = 'v')
    plt.xlabel(colNames[14])
    plt.ylabel(colNames[3])

    plt.show()



columns = ['symboling','normalized-losses','make','fuel-type','aspiration','num-of-doors','body-style','drive-wheels','engine-location','wheel-base','length','width','height','curb-weight','engine-type','num-of-cylinders','engine-size','fuel-system','bore','stroke','compression-ratio','horsepower','peak-rpm','city-mpg','highway-mpg','price']
categorical = ['make','fuel-type','aspiration','num-of-doors','body-style','drive-wheels','engine-location','engine-type','num-of-cylinders','fuel-system']

#TestFunc Runs all the python functions for Part 2
testFunc()
#Main runs the python data analysis needed for Part 3
main()
```

symboling,0.8341463414634146
normalized-losses,122.0
wheel-base,98.75658536585378
length,174.04926829268305
width,65.90780487804875
height,53.724878048780525
curb-weight,2555.5658536585365
engine-size,126.90731707317073
bore,3.329751243781096
stroke,3.2554228855721337
compression-ratio,10.142536585365855
horsepower,104.25615763546797
peak-rpm,5125.369458128079
city-mpg,25.21951219512195
highway-mpg,30.75121951219512
price,13207.129353233831
make_alfa-romero,0.014634146341463415
make_audi,0.03414634146341464
make_bmw,0.03902439024390244
make_chevrolet,0.014634146341463415
make_dodge,0.04390243902439024
make_honda,0.06341463414634146
make_isuzu,0.01951219512195122
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make_mazda,0.08292682926829269
make_mercedes-benz,0.03902439024390244
make_mercury,0.004878048780487805
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make_nissan,0.08780487804878048
make_peugot,0.05365853658536585
make_plymouth,0.03414634146341464
make_porsche,0.024390243902439025
make_renault,0.00975609756097561
make_saab,0.02926829268292683
make_subaru,0.05853658536585366
make_toyota,0.15609756097560976
make_volkswagen,0.05853658536585366
make_volvo,0.05365853658536585
fuel-type_diesel,0.0975609756097561
fuel-type_gas,0.9024390243902439
aspiration_std,0.8195121951219512
aspiration_turbo,0.18048780487804877
num-of-doors_four,0.5560975609756098
num-of-doors_two,0.43414634146341463
body-style_convertible,0.02926829268292683
body-style_hardtop,0.03902439024390244
body-style_hatchback,0.34146341463414637
body-style_sedan,0.4682926829268293
body-style_wagon,0.12195121951219512
drive-wheels_4wd,0.04390243902439024

```
drive-wheels_fwd,0.5853658536585366
drive-wheels_rwd,0.37073170731707317
engine-location_front,0.9853658536585366
engine-location_rear,0.014634146341463415
engine-type_dohc,0.05853658536585366
engine-type_dohcv,0.004878048780487805
engine-type_l,0.05853658536585366
engine-type_ohc,0.7219512195121951
engine-type_ohcf,0.07317073170731707
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