

Linear Regression

2023-09-24

```
Auto <- read_excel("C:/Users/I068117/UT_Machine Learning/Auto.xlsx")
names(Auto)

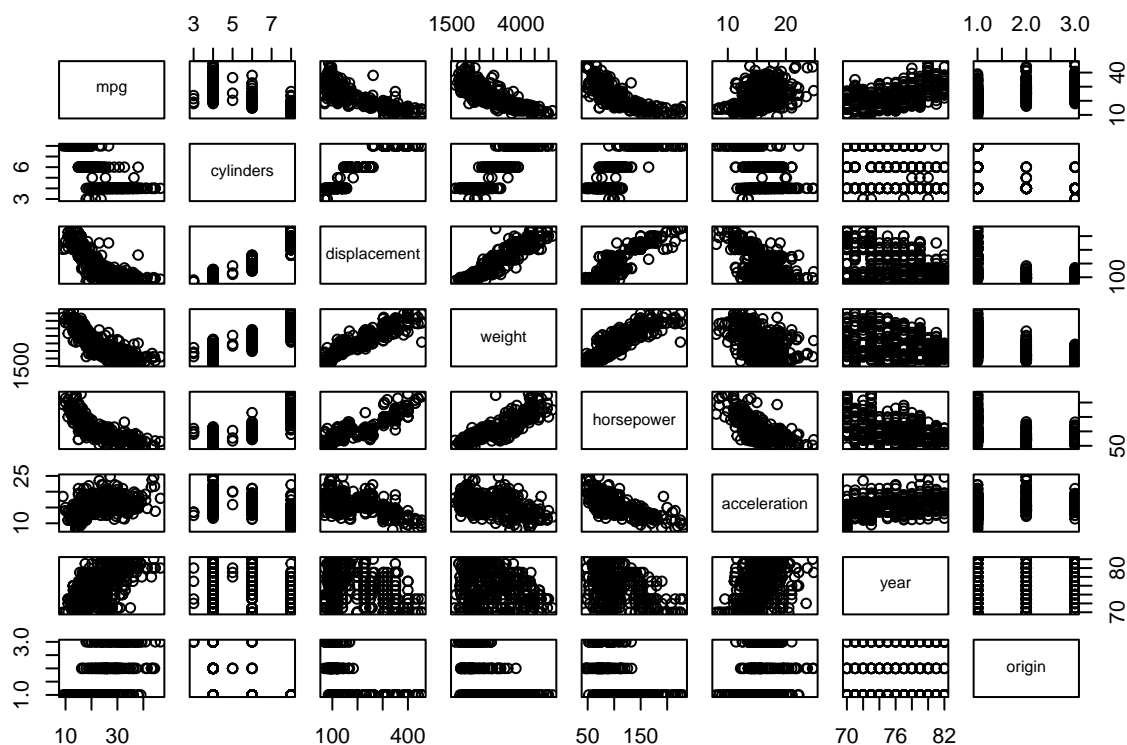
## [1] "mpg"          "cylinders"    "displacement" "horsepower"   "weight"
## [6] "acceleration" "year"         "origin"       "name"
```

Scatterplot of matrix of all variables

```
# converting horsepower from character to numeric
Auto$horsepower <- as.numeric(Auto$horsepower)

## Warning: NAs introduced by coercion

pairs(~ mpg + cylinders + displacement + weight + horsepower +
acceleration + year + origin, Auto)
```



Correlation plot of all numeric variables

```
# Selecting only the numeric X predictors

numeric_data <- Auto[sapply(Auto, is.numeric)]

# Remove rows with missing values
cleaned_data <- na.omit(numeric_data)

cor(cleaned_data)

##              mpg  cylinders displacement horsepower    weight
## mpg          1.0000000 -0.7776175   -0.8051269 -0.7784268 -0.8322442
## cylinders    -0.7776175  1.0000000    0.9508233  0.8429834  0.8975273
## displacement -0.8051269  0.9508233    1.0000000  0.8972570  0.9329944
## horsepower   -0.7784268  0.8429834    0.8972570  1.0000000  0.8645377
## weight       -0.8322442  0.8975273    0.9329944  0.8645377  1.0000000
## acceleration  0.4233285 -0.5046834   -0.5438005 -0.6891955 -0.4168392
## year         0.5805410 -0.3456474   -0.3698552 -0.4163615 -0.3091199
## origin       0.5652088 -0.5689316   -0.6145351 -0.4551715 -0.5850054
##              acceleration    year    origin
## mpg          0.4233285  0.5805410  0.5652088
## cylinders    -0.5046834 -0.3456474 -0.5689316
## displacement -0.5438005 -0.3698552 -0.6145351
## horsepower   -0.6891955 -0.4163615 -0.4551715
## weight       -0.4168392 -0.3091199 -0.5850054
## acceleration  1.0000000  0.2903161  0.2127458
## year         0.2903161  1.0000000  0.1815277
## origin       0.2127458  0.1815277  1.0000000
```

multiple linear regression with mpg as the response and all other variables except name as the predictors.

```
mlr <- lm(mpg ~ cylinders + displacement + weight + horsepower +
acceleration + year + origin, data= cleaned_data )

summary (mlr)

##
## Call:
## lm(formula = mpg ~ cylinders + displacement + weight + horsepower +
##     acceleration + year + origin, data = cleaned_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -9.5903 -2.1565 -0.1169  1.8690 13.0604
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) -17.218435   4.644294  -3.707  0.00024 ***
## cylinders    -0.493376   0.323282  -1.526  0.12780
## displacement  0.019896   0.007515   2.647  0.00844 **
## weight       -0.006474   0.000652  -9.929 < 2e-16 ***
## horsepower   -0.016951   0.013787  -1.230  0.21963
```

```
## acceleration 0.080576 0.098845 0.815 0.41548
## year 0.750773 0.050973 14.729 < 2e-16 ***
## origin 1.426141 0.278136 5.127 4.67e-07 ***
## ---
## Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.328 on 384 degrees of freedom
## Multiple R-squared: 0.8215, Adjusted R-squared: 0.8182
## F-statistic: 252.4 on 7 and 384 DF, p-value: < 2.2e-16
```

Interpretation

Q: Is there a relationship between the predictors and the response? A: Yes

Q: Which predictors appear to have a statistically significant relationship to the response? A: Predictors with less than 5 % p-value ($p < 0.05$) are statistically significant as we can reject the null hypothesis.

Displacement: The “displacement” predictor is statistically significant ($p = 0.00844$)

Weight: The “weight” predictor is statistically significant ($p < 0.0000000000000002$)

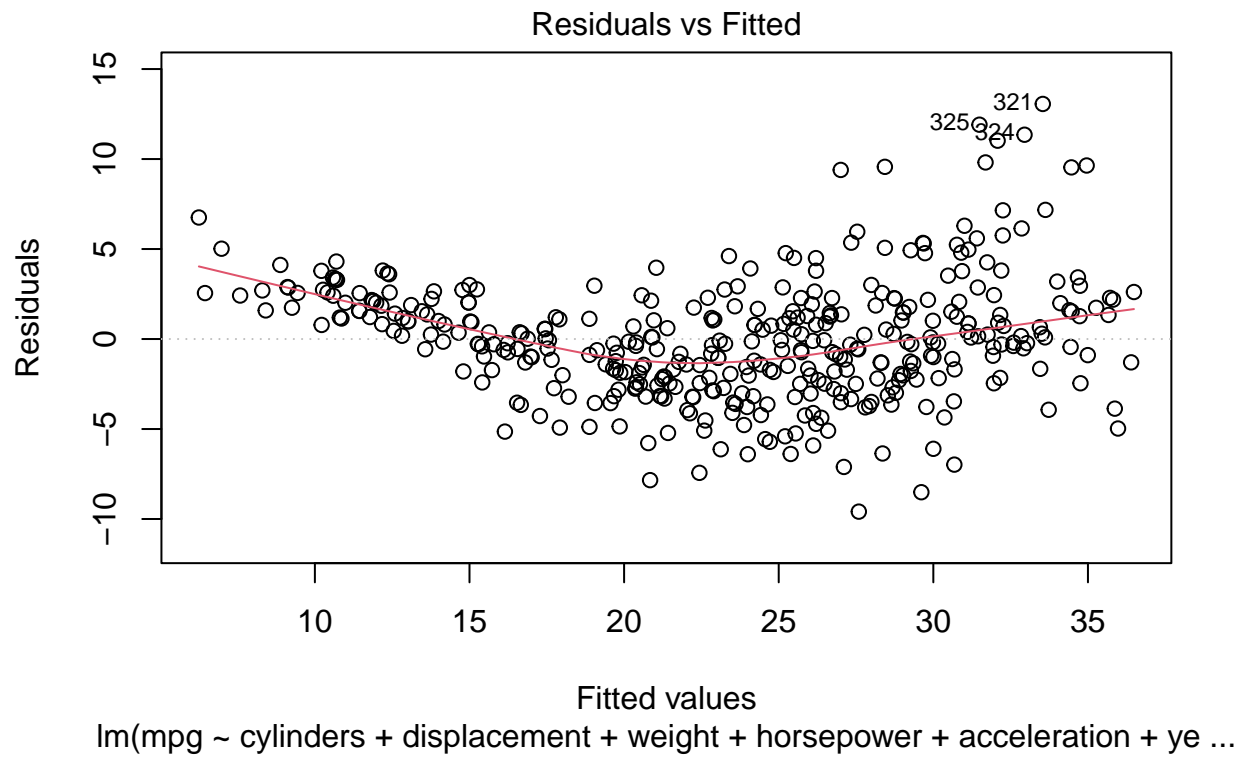
Year: The “year” predictor is statistically significant ($p < 0.0000000000000002$).

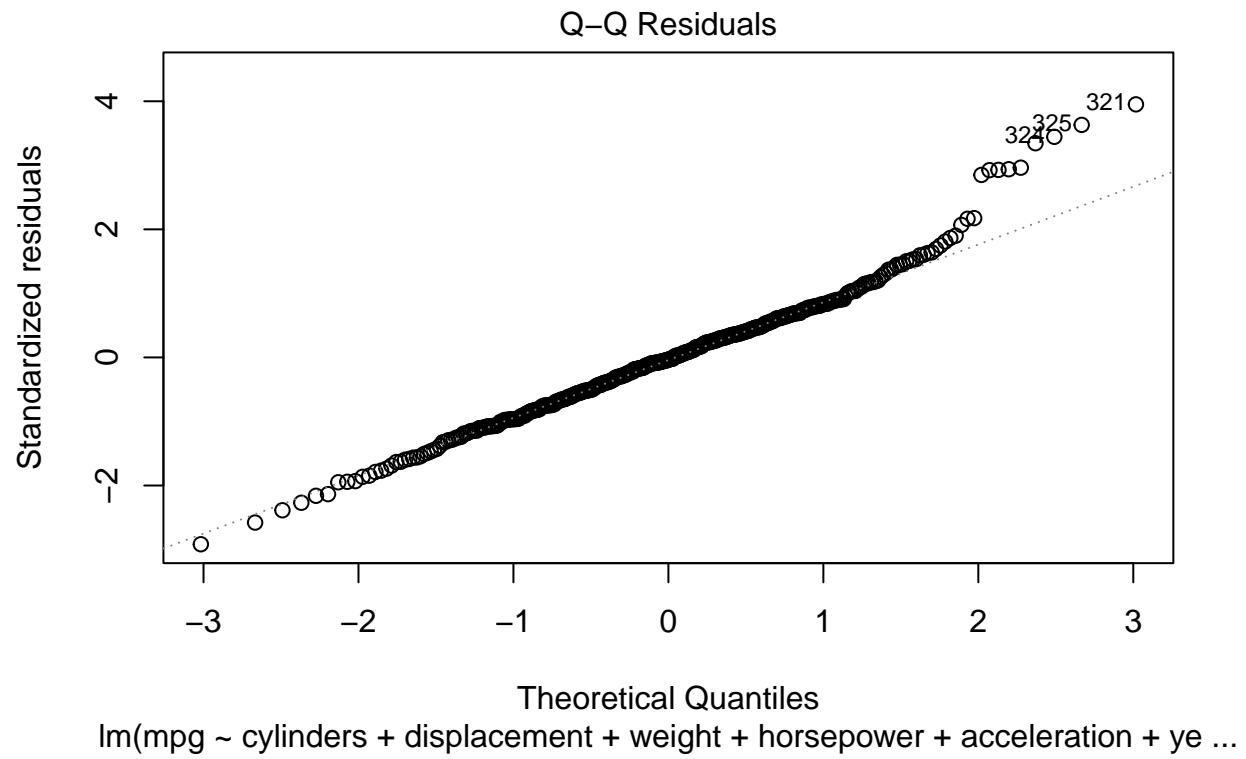
Origin: The “origin” predictor is statistically significant ($p = 0.000000467$).

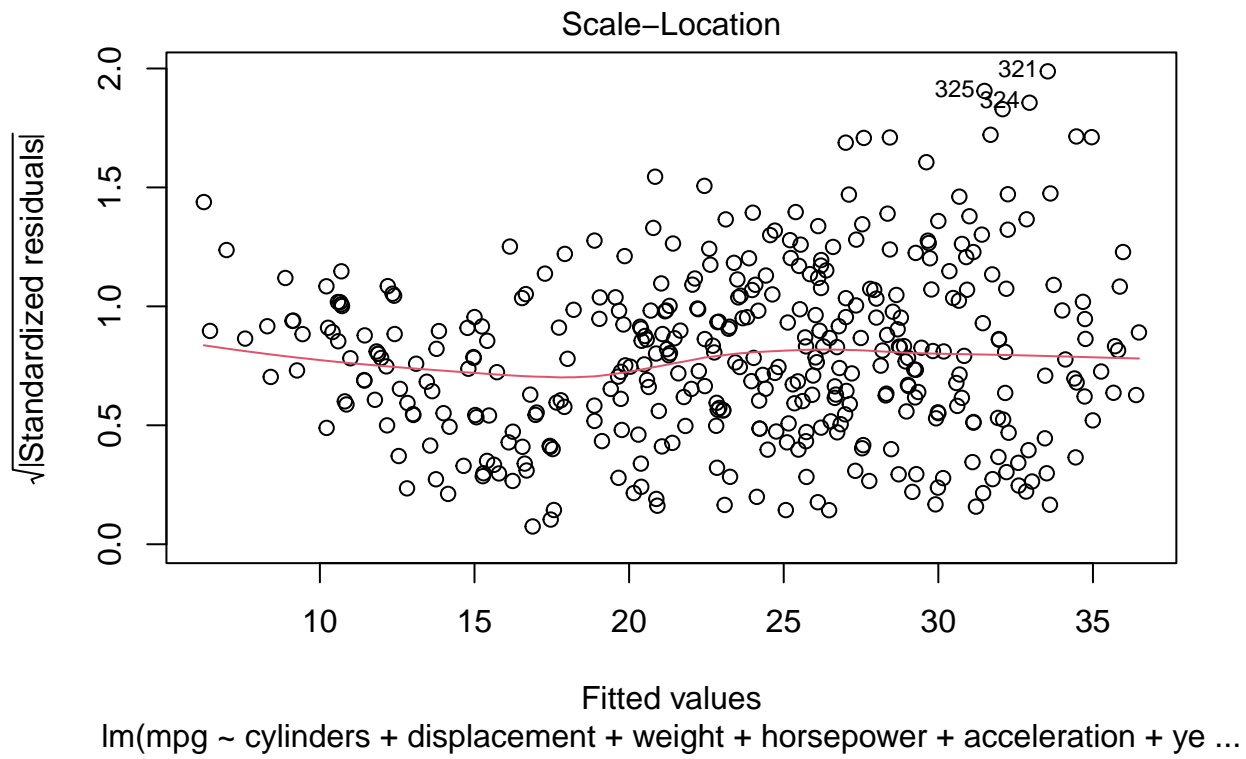
Q: What does the coefficient for the year variable suggest? 1. There is a positive relation between mpg & year 2. For 1 unit change in year, mpg increases by 0.750773

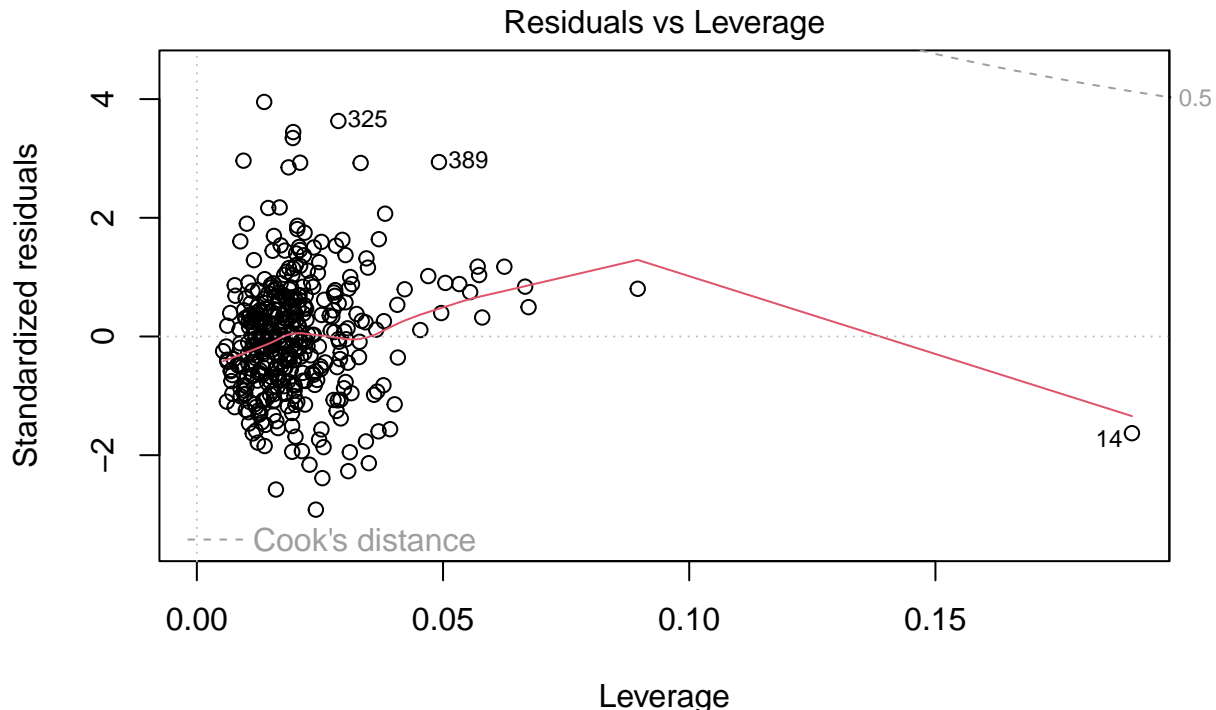
Use the `plot()` function to produce diagnostic plots of the linear regression fit. Comment on any problems you see with the fit. Do the residual plots suggest any unusually large outliers?

```
plot(mlr)
```









Interpretation:

The residual error is not normally distributed around the horizontal line and there is a curve/pattern in the distribution suggestion linear regression may not be a good fit. There are also large outliers in the residual plot

Use the * and : symbols to fit linear regression models with interaction effects. Do any interactions appear to be statistically significant?

```
#Interaction for all variables
```

```
interaction_model <- lm(mpg ~ cylinders * displacement * weight * horsepower *  
acceleration * year * origin, data= cleaned_data )
```

```
# Print the summary of the model
```

```
summary(interaction_model)
```

```
##
```

```
## Call:
```

```
## lm(formula = mpg ~ cylinders * displacement * weight * horsepower *  
## acceleration * year * origin, data = cleaned_data)
```

```
##
```

```
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max  
## -6.4533 -1.0707  0.0000  0.9962  9.1994
```

```
##
```

```
## Coefficients: (15 not defined because of singularities)
```

##	Estimate
## (Intercept)	6.785e+04
## cylinders	-1.585e+04
## displacement	-1.419e+03
## weight	4.373e+01
## horsepower	-1.300e+03
## acceleration	-8.400e+03
## year	6.232e+02
## origin	-5.789e+04
## cylinders:displacement	3.404e+02
## cylinders:weight	-1.158e+01
## displacement:weight	2.313e-01
## cylinders:horsepower	3.118e+02
## displacement:horsepower	8.962e+00
## weight:horsepower	4.055e-01
## cylinders:acceleration	2.009e+03
## displacement:acceleration	1.682e+01
## weight:acceleration	3.748e-01
## horsepower:acceleration	1.076e+01
## cylinders:year	-1.748e+02
## displacement:year	8.341e+00
## weight:year	-9.176e-01
## horsepower:year	1.607e+00
## acceleration:year	9.485e+01
## cylinders:origin	1.319e+04
## displacement:origin	1.351e+03
## weight:origin	-4.564e+01
## horsepower:origin	1.241e+03
## acceleration:origin	7.439e+03
## year:origin	-7.745e+02
## cylinders:displacement:weight	-4.967e-02
## cylinders:displacement:horsepower	-2.075e+00
## cylinders:weight:horsepower	-9.443e-02
## displacement:weight:horsepower	-2.805e-03
## cylinders:displacement:acceleration	-3.446e+00
## cylinders:weight:acceleration	-3.977e-02
## displacement:weight:acceleration	-3.174e-03
## cylinders:horsepower:acceleration	-1.650e+00
## displacement:horsepower:acceleration	-6.798e-02
## weight:horsepower:acceleration	-3.717e-03
## cylinders:displacement:year	-1.871e+00
## cylinders:weight:year	2.400e-01
## displacement:weight:year	-7.017e-04
## cylinders:horsepower:year	-1.675e-01
## displacement:horsepower:year	-1.594e-02
## weight:horsepower:year	-6.825e-04
## cylinders:acceleration:year	-2.225e+01
## displacement:acceleration:year	-1.068e-01
## weight:acceleration:year	-6.359e-03
## horsepower:acceleration:year	-1.653e-01
## cylinders:displacement:origin	-3.266e+02
## cylinders:weight:origin	1.216e+01
## displacement:weight:origin	-2.103e-01
## cylinders:horsepower:origin	-2.947e+02

## displacement:horsepower:origin	-8.446e+00
## weight:horsepower:origin	-3.992e-01
## cylinders:acceleration:origin	-1.777e+03
## displacement:acceleration:origin	-1.175e+01
## weight:acceleration:origin	-1.515e-01
## horsepower:acceleration:origin	-3.670e+00
## cylinders:year:origin	2.131e+02
## displacement:year:origin	-7.372e+00
## weight:year:origin	9.512e-01
## horsepower:year:origin	-6.129e-01
## acceleration:year:origin	-8.096e+01
## cylinders:displacement:weight:horsepower	6.153e-04
## cylinders:displacement:weight:acceleration	3.041e-04
## cylinders:displacement:horsepower:acceleration	8.053e-03
## cylinders:weight:horsepower:acceleration	3.603e-04
## displacement:weight:horsepower:acceleration	2.971e-05
## cylinders:displacement:weight:year	5.645e-05
## cylinders:displacement:horsepower:year	1.436e-03
## cylinders:weight:horsepower:year	5.134e-05
## displacement:weight:horsepower:year	6.861e-06
## cylinders:displacement:acceleration:year	1.517e-02
## cylinders:weight:acceleration:year	7.543e-04
## displacement:weight:acceleration:year	4.571e-05
## cylinders:horsepower:acceleration:year	2.417e-02
## displacement:horsepower:acceleration:year	1.006e-03
## weight:horsepower:acceleration:year	5.842e-05
## cylinders:displacement:weight:origin	4.576e-02
## cylinders:displacement:horsepower:origin	1.974e+00
## cylinders:weight:horsepower:origin	9.146e-02
## displacement:weight:horsepower:origin	2.646e-03
## cylinders:displacement:acceleration:origin	2.354e+00
## cylinders:weight:acceleration:origin	-1.186e-02
## displacement:weight:acceleration:origin	1.539e-03
## cylinders:horsepower:acceleration:origin	-5.449e-02
## displacement:horsepower:acceleration:origin	2.922e-02
## weight:horsepower:acceleration:origin	2.184e-03
## cylinders:displacement:year:origin	1.676e+00
## cylinders:weight:year:origin	-2.488e-01
## displacement:weight:year:origin	3.907e-04
## cylinders:horsepower:year:origin	-8.713e-02
## displacement:horsepower:year:origin	8.343e-03
## weight:horsepower:year:origin	5.097e-04
## cylinders:acceleration:year:origin	1.900e+01
## displacement:acceleration:year:origin	3.522e-02
## weight:acceleration:year:origin	2.916e-03
## horsepower:acceleration:year:origin	6.027e-02
## cylinders:displacement:weight:horsepower:acceleration	-2.295e-06
## cylinders:displacement:weight:horsepower:year	-4.178e-07
## cylinders:displacement:weight:acceleration:year	-4.299e-06
## cylinders:displacement:horsepower:acceleration:year	-1.124e-04
## cylinders:weight:horsepower:acceleration:year	-5.449e-06
## displacement:weight:horsepower:acceleration:year	-4.413e-07
## cylinders:displacement:weight:horsepower:origin	-5.872e-04
## cylinders:displacement:weight:acceleration:origin	NA

## cylinders:displacement:horsepower:acceleration:origin	NA
## cylinders:weight:horsepower:acceleration:origin	NA
## displacement:weight:horsepower:acceleration:origin	-1.684e-05
## cylinders:displacement:weight:year:origin	NA
## cylinders:displacement:horsepower:year:origin	NA
## cylinders:weight:horsepower:year:origin	NA
## displacement:weight:horsepower:year:origin	-4.410e-06
## cylinders:displacement:acceleration:year:origin	NA
## cylinders:weight:acceleration:year:origin	NA
## displacement:weight:acceleration:year:origin	-2.222e-05
## cylinders:horsepower:acceleration:year:origin	NA
## displacement:horsepower:acceleration:year:origin	-4.537e-04
## weight:horsepower:acceleration:year:origin	-3.306e-05
## cylinders:displacement:weight:horsepower:acceleration:year	3.293e-08
## cylinders:displacement:weight:horsepower:acceleration:origin	NA
## cylinders:displacement:weight:horsepower:year:origin	NA
## cylinders:displacement:weight:acceleration:year:origin	NA
## cylinders:displacement:horsepower:acceleration:year:origin	NA
## cylinders:weight:horsepower:acceleration:year:origin	NA
## displacement:weight:horsepower:acceleration:year:origin	2.522e-07
## cylinders:displacement:weight:horsepower:acceleration:year:origin	NA
##	Std. Error
## (Intercept)	5.058e+04
## cylinders	9.813e+03
## displacement	9.892e+02
## weight	3.998e+01
## horsepower	9.564e+02
## acceleration	5.946e+03
## year	7.248e+02
## origin	4.376e+04
## cylinders:displacement	2.325e+02
## cylinders:weight	9.975e+00
## displacement:weight	1.695e-01
## cylinders:horsepower	2.133e+02
## displacement:horsepower	6.394e+00
## weight:horsepower	3.201e-01
## cylinders:acceleration	1.380e+03
## displacement:acceleration	1.593e+01
## weight:acceleration	7.925e-01
## horsepower:acceleration	2.313e+01
## cylinders:year	1.665e+02
## displacement:year	6.084e+00
## weight:year	7.729e-01
## horsepower:year	4.964e+00
## acceleration:year	6.703e+01
## cylinders:origin	9.455e+03
## displacement:origin	9.883e+02
## weight:origin	3.692e+01
## horsepower:origin	9.258e+02
## acceleration:origin	5.873e+03
## year:origin	5.774e+02
## cylinders:displacement:weight	3.278e-02
## cylinders:displacement:horsepower	1.370e+00
## cylinders:weight:horsepower	6.523e-02

## displacement:weight:horsepower	2.095e-03
## cylinders:displacement:acceleration	1.925e+00
## cylinders:weight:acceleration	8.196e-02
## displacement:weight:acceleration	4.950e-03
## cylinders:horsepower:acceleration	2.294e+00
## displacement:horsepower:acceleration	1.616e-01
## weight:horsepower:acceleration	9.754e-03
## cylinders:displacement:year	1.240e+00
## cylinders:weight:year	1.956e-01
## displacement:weight:year	1.063e-03
## cylinders:horsepower:year	4.792e-01
## displacement:horsepower:year	3.453e-02
## weight:horsepower:year	2.087e-03
## cylinders:acceleration:year	1.523e+01
## displacement:acceleration:year	1.814e-01
## weight:acceleration:year	1.018e-02
## horsepower:acceleration:year	2.979e-01
## cylinders:displacement:origin	2.342e+02
## cylinders:weight:origin	9.713e+00
## displacement:weight:origin	1.620e-01
## cylinders:horsepower:origin	2.146e+02
## displacement:horsepower:origin	6.208e+00
## weight:horsepower:origin	2.979e-01
## cylinders:acceleration:origin	1.391e+03
## displacement:acceleration:origin	1.128e+01
## weight:acceleration:origin	3.466e-01
## horsepower:acceleration:origin	1.032e+01
## cylinders:year:origin	1.533e+02
## displacement:year:origin	5.763e+00
## weight:year:origin	7.427e-01
## horsepower:year:origin	2.320e+00
## acceleration:year:origin	6.551e+01
## cylinders:displacement:weight:horsepower	4.125e-04
## cylinders:displacement:weight:acceleration	4.129e-04
## cylinders:displacement:horsepower:acceleration	1.331e-02
## cylinders:weight:horsepower:acceleration	8.587e-04
## displacement:weight:horsepower:acceleration	5.895e-05
## cylinders:displacement:weight:year	8.960e-05
## cylinders:displacement:horsepower:year	2.859e-03
## cylinders:weight:horsepower:year	1.863e-04
## displacement:weight:horsepower:year	1.258e-05
## cylinders:displacement:acceleration:year	1.668e-02
## cylinders:weight:acceleration:year	1.042e-03
## displacement:weight:acceleration:year	6.427e-05
## cylinders:horsepower:acceleration:year	2.951e-02
## displacement:horsepower:acceleration:year	2.111e-03
## weight:horsepower:acceleration:year	1.252e-04
## cylinders:displacement:weight:origin	3.286e-02
## cylinders:displacement:horsepower:origin	1.380e+00
## cylinders:weight:horsepower:origin	6.533e-02
## displacement:weight:horsepower:origin	2.022e-03
## cylinders:displacement:acceleration:origin	1.622e+00
## cylinders:weight:acceleration:origin	9.461e-03
## displacement:weight:acceleration:origin	3.037e-03

## cylinders:horsepower:acceleration:origin	2.162e-01
## displacement:horsepower:acceleration:origin	8.997e-02
## weight:horsepower:acceleration:origin	4.625e-03
## cylinders:displacement:year:origin	1.247e+00
## cylinders:weight:year:origin	1.927e-01
## displacement:weight:year:origin	6.625e-04
## cylinders:horsepower:year:origin	7.737e-02
## displacement:horsepower:year:origin	1.938e-02
## weight:horsepower:year:origin	9.857e-04
## cylinders:acceleration:year:origin	1.533e+01
## displacement:acceleration:year:origin	9.168e-02
## weight:acceleration:year:origin	4.536e-03
## horsepower:acceleration:year:origin	1.337e-01
## cylinders:displacement:weight:horsepower:acceleration	4.466e-06
## cylinders:displacement:weight:horsepower:year	9.705e-07
## cylinders:displacement:weight:acceleration:year	5.405e-06
## cylinders:displacement:horsepower:acceleration:year	1.748e-04
## cylinders:weight:horsepower:acceleration:year	1.111e-05
## displacement:weight:horsepower:acceleration:year	7.632e-07
## cylinders:displacement:weight:horsepower:origin	4.152e-04
## cylinders:displacement:weight:acceleration:origin	NA
## cylinders:displacement:horsepower:acceleration:origin	NA
## cylinders:weight:horsepower:acceleration:origin	NA
## displacement:weight:horsepower:acceleration:origin	3.791e-05
## cylinders:displacement:weight:year:origin	NA
## cylinders:displacement:horsepower:year:origin	NA
## cylinders:weight:horsepower:year:origin	NA
## displacement:weight:horsepower:year:origin	8.158e-06
## cylinders:displacement:acceleration:year:origin	NA
## cylinders:weight:acceleration:year:origin	NA
## displacement:weight:acceleration:year:origin	3.907e-05
## cylinders:horsepower:acceleration:year:origin	NA
## displacement:horsepower:acceleration:year:origin	1.169e-03
## weight:horsepower:acceleration:year:origin	5.950e-05
## cylinders:displacement:weight:horsepower:acceleration:year	5.819e-08
## cylinders:displacement:weight:horsepower:acceleration:origin	NA
## cylinders:displacement:weight:horsepower:year:origin	NA
## cylinders:displacement:weight:acceleration:year:origin	NA
## cylinders:displacement:horsepower:acceleration:year:origin	NA
## cylinders:weight:horsepower:acceleration:year:origin	NA
## displacement:weight:horsepower:acceleration:year:origin	4.889e-07
## cylinders:displacement:weight:horsepower:acceleration:year:origin	NA
##	t value
## (Intercept)	1.342
## cylinders	-1.616
## displacement	-1.434
## weight	1.094
## horsepower	-1.360
## acceleration	-1.413
## year	0.860
## origin	-1.323
## cylinders:displacement	1.464
## cylinders:weight	-1.161
## displacement:weight	1.365

## cylinders:horsepower	1.461
## displacement:horsepower	1.402
## weight:horsepower	1.267
## cylinders:acceleration	1.456
## displacement:acceleration	1.056
## weight:acceleration	0.473
## horsepower:acceleration	0.465
## cylinders:year	-1.049
## displacement:year	1.371
## weight:year	-1.187
## horsepower:year	0.324
## acceleration:year	1.415
## cylinders:origin	1.395
## displacement:origin	1.367
## weight:origin	-1.236
## horsepower:origin	1.340
## acceleration:origin	1.267
## year:origin	-1.341
## cylinders:displacement:weight	-1.515
## cylinders:displacement:horsepower	-1.515
## cylinders:weight:horsepower	-1.448
## displacement:weight:horsepower	-1.339
## cylinders:displacement:acceleration	-1.790
## cylinders:weight:acceleration	-0.485
## displacement:weight:acceleration	-0.641
## cylinders:horsepower:acceleration	-0.719
## displacement:horsepower:acceleration	-0.421
## weight:horsepower:acceleration	-0.381
## cylinders:displacement:year	-1.510
## cylinders:weight:year	1.227
## displacement:weight:year	-0.660
## cylinders:horsepower:year	-0.349
## displacement:horsepower:year	-0.462
## weight:horsepower:year	-0.327
## cylinders:acceleration:year	-1.461
## displacement:acceleration:year	-0.589
## weight:acceleration:year	-0.625
## horsepower:acceleration:year	-0.555
## cylinders:displacement:origin	-1.394
## cylinders:weight:origin	1.252
## displacement:weight:origin	-1.298
## cylinders:horsepower:origin	-1.373
## displacement:horsepower:origin	-1.361
## weight:horsepower:origin	-1.340
## cylinders:acceleration:origin	-1.278
## displacement:acceleration:origin	-1.042
## weight:acceleration:origin	-0.437
## horsepower:acceleration:origin	-0.356
## cylinders:year:origin	1.390
## displacement:year:origin	-1.279
## weight:year:origin	1.281
## horsepower:year:origin	-0.264
## acceleration:year:origin	-1.236
## cylinders:displacement:weight:horsepower	1.492

## cylinders:displacement:weight:acceleration	0.737
## cylinders:displacement:horsepower:acceleration	0.605
## cylinders:weight:horsepower:acceleration	0.420
## displacement:weight:horsepower:acceleration	0.504
## cylinders:displacement:weight:year	0.630
## cylinders:displacement:horsepower:year	0.502
## cylinders:weight:horsepower:year	0.276
## displacement:weight:horsepower:year	0.545
## cylinders:displacement:acceleration:year	0.910
## cylinders:weight:acceleration:year	0.724
## displacement:weight:acceleration:year	0.711
## cylinders:horsepower:acceleration:year	0.819
## displacement:horsepower:acceleration:year	0.477
## weight:horsepower:acceleration:year	0.467
## cylinders:displacement:weight:origin	1.392
## cylinders:displacement:horsepower:origin	1.430
## cylinders:weight:horsepower:origin	1.400
## displacement:weight:horsepower:origin	1.309
## cylinders:displacement:acceleration:origin	1.451
## cylinders:weight:acceleration:origin	-1.254
## displacement:weight:acceleration:origin	0.507
## cylinders:horsepower:acceleration:origin	-0.252
## displacement:horsepower:acceleration:origin	0.325
## weight:horsepower:acceleration:origin	0.472
## cylinders:displacement:year:origin	1.344
## cylinders:weight:year:origin	-1.291
## displacement:weight:year:origin	0.590
## cylinders:horsepower:year:origin	-1.126
## displacement:horsepower:year:origin	0.430
## weight:horsepower:year:origin	0.517
## cylinders:acceleration:year:origin	1.239
## displacement:acceleration:year:origin	0.384
## weight:acceleration:year:origin	0.643
## horsepower:acceleration:year:origin	0.451
## cylinders:displacement:weight:horsepower:acceleration	-0.514
## cylinders:displacement:weight:horsepower:year	-0.430
## cylinders:displacement:weight:acceleration:year	-0.795
## cylinders:displacement:horsepower:acceleration:year	-0.643
## cylinders:weight:horsepower:acceleration:year	-0.491
## displacement:weight:horsepower:acceleration:year	-0.578
## cylinders:displacement:weight:horsepower:origin	-1.414
## cylinders:displacement:weight:acceleration:origin	NA
## cylinders:displacement:horsepower:acceleration:origin	NA
## cylinders:weight:horsepower:acceleration:origin	NA
## displacement:weight:horsepower:acceleration:origin	-0.444
## cylinders:displacement:weight:year:origin	NA
## cylinders:displacement:horsepower:year:origin	NA
## cylinders:weight:horsepower:year:origin	NA
## displacement:weight:horsepower:year:origin	-0.541
## cylinders:displacement:acceleration:year:origin	NA
## cylinders:weight:acceleration:year:origin	NA
## displacement:weight:acceleration:year:origin	-0.569
## cylinders:horsepower:acceleration:year:origin	NA
## displacement:horsepower:acceleration:year:origin	-0.388

## weight:horsepower:acceleration:year:origin	-0.556
## cylinders:displacement:weight:horsepower:acceleration:year	0.566
## cylinders:displacement:weight:horsepower:acceleration:origin	NA
## cylinders:displacement:weight:horsepower:year:origin	NA
## cylinders:displacement:weight:acceleration:year:origin	NA
## cylinders:displacement:horsepower:acceleration:year:origin	NA
## cylinders:weight:horsepower:acceleration:year:origin	NA
## displacement:weight:horsepower:acceleration:year:origin	0.516
## cylinders:displacement:weight:horsepower:acceleration:year:origin	NA
##	Pr(> t)
## (Intercept)	0.1808
## cylinders	0.1073
## displacement	0.1527
## weight	0.2750
## horsepower	0.1751
## acceleration	0.1589
## year	0.3906
## origin	0.1869
## cylinders:displacement	0.1444
## cylinders:weight	0.2468
## displacement:weight	0.1735
## cylinders:horsepower	0.1450
## displacement:horsepower	0.1622
## weight:horsepower	0.2063
## cylinders:acceleration	0.1467
## displacement:acceleration	0.2920
## weight:acceleration	0.6367
## horsepower:acceleration	0.6421
## cylinders:year	0.2949
## displacement:year	0.1715
## weight:year	0.2361
## horsepower:year	0.7464
## acceleration:year	0.1582
## cylinders:origin	0.1641
## displacement:origin	0.1726
## weight:origin	0.2175
## horsepower:origin	0.1813
## acceleration:origin	0.2064
## year:origin	0.1809
## cylinders:displacement:weight	0.1308
## cylinders:displacement:horsepower	0.1310
## cylinders:weight:horsepower	0.1488
## displacement:weight:horsepower	0.1816
## cylinders:displacement:acceleration	0.0745
## cylinders:weight:acceleration	0.6279
## displacement:weight:acceleration	0.5220
## cylinders:horsepower:acceleration	0.4726
## displacement:horsepower:acceleration	0.6744
## weight:horsepower:acceleration	0.7035
## cylinders:displacement:year	0.1323
## cylinders:weight:year	0.2208
## displacement:weight:year	0.5098
## cylinders:horsepower:year	0.7270
## displacement:horsepower:year	0.6447

## weight:horsepower:year	0.7439
## cylinders:acceleration:year	0.1452
## displacement:acceleration:year	0.5565
## weight:acceleration:year	0.5326
## horsepower:acceleration:year	0.5794
## cylinders:displacement:origin	0.1644
## cylinders:weight:origin	0.2118
## displacement:weight:origin	0.1953
## cylinders:horsepower:origin	0.1708
## displacement:horsepower:origin	0.1747
## weight:horsepower:origin	0.1813
## cylinders:acceleration:origin	0.2025
## displacement:acceleration:origin	0.2985
## weight:acceleration:origin	0.6624
## horsepower:acceleration:origin	0.7223
## cylinders:year:origin	0.1657
## displacement:year:origin	0.2019
## weight:year:origin	0.2014
## horsepower:year:origin	0.7919
## acceleration:year:origin	0.2175
## cylinders:displacement:weight:horsepower	0.1369
## cylinders:displacement:weight:acceleration	0.4620
## cylinders:displacement:horsepower:acceleration	0.5458
## cylinders:weight:horsepower:acceleration	0.6751
## displacement:weight:horsepower:acceleration	0.6147
## cylinders:displacement:weight:year	0.5292
## cylinders:displacement:horsepower:year	0.6160
## cylinders:weight:horsepower:year	0.7831
## displacement:weight:horsepower:year	0.5860
## cylinders:displacement:acceleration:year	0.3639
## cylinders:weight:acceleration:year	0.4696
## displacement:weight:acceleration:year	0.4776
## cylinders:horsepower:acceleration:year	0.4134
## displacement:horsepower:acceleration:year	0.6339
## weight:horsepower:acceleration:year	0.6411
## cylinders:displacement:weight:origin	0.1649
## cylinders:displacement:horsepower:origin	0.1538
## cylinders:weight:horsepower:origin	0.1626
## displacement:weight:horsepower:origin	0.1917
## cylinders:displacement:acceleration:origin	0.1479
## cylinders:weight:acceleration:origin	0.2109
## displacement:weight:acceleration:origin	0.6127
## cylinders:horsepower:acceleration:origin	0.8012
## displacement:horsepower:acceleration:origin	0.7456
## weight:horsepower:acceleration:origin	0.6372
## cylinders:displacement:year:origin	0.1800
## cylinders:weight:year:origin	0.1977
## displacement:weight:year:origin	0.5558
## cylinders:horsepower:year:origin	0.2611
## displacement:horsepower:year:origin	0.6672
## weight:horsepower:year:origin	0.6055
## cylinders:acceleration:year:origin	0.2162
## displacement:acceleration:year:origin	0.7011
## weight:acceleration:year:origin	0.5208


```
## horsepower:acceleration:year:origin 0.6525
## cylinders:displacement:weight:horsepower:acceleration 0.6078
## cylinders:displacement:weight:horsepower:year 0.6672
## cylinders:displacement:weight:acceleration:year 0.4270
## cylinders:displacement:horsepower:acceleration:year 0.5206
## cylinders:weight:horsepower:acceleration:year 0.6240
## displacement:weight:horsepower:acceleration:year 0.5636
## cylinders:displacement:weight:horsepower:origin 0.1584
## cylinders:displacement:weight:acceleration:origin NA
## cylinders:displacement:horsepower:acceleration:origin NA
## cylinders:weight:horsepower:acceleration:origin NA
## displacement:weight:horsepower:acceleration:origin 0.6573
## cylinders:displacement:weight:year:origin NA
## cylinders:displacement:horsepower:year:origin NA
## cylinders:weight:horsepower:year:origin NA
## displacement:weight:horsepower:year:origin 0.5893
## cylinders:displacement:acceleration:year:origin NA
## cylinders:weight:acceleration:year:origin NA
## displacement:weight:acceleration:year:origin 0.5700
## cylinders:horsepower:acceleration:year:origin NA
## displacement:horsepower:acceleration:year:origin 0.6983
## weight:horsepower:acceleration:year:origin 0.5789
## cylinders:displacement:weight:horsepower:acceleration:year 0.5719
## cylinders:displacement:weight:horsepower:acceleration:origin NA
## cylinders:displacement:weight:horsepower:year:origin NA
## cylinders:displacement:weight:acceleration:year:origin NA
## cylinders:displacement:horsepower:acceleration:year:origin NA
## cylinders:weight:horsepower:acceleration:year:origin NA
## displacement:weight:horsepower:acceleration:year:origin 0.6064
## cylinders:displacement:weight:horsepower:acceleration:year:origin NA
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.418 on 279 degrees of freedom
## Multiple R-squared:  0.9315, Adjusted R-squared:  0.904
## F-statistic: 33.88 on 112 and 279 DF,  p-value: < 2.2e-16
```

Interpretation: No predictors seems statistically significant

```
# 2 interactions of each variables
```

```
interaction_model2 =lm(mpg ~ (cylinders + displacement + weight + horsepower +
  acceleration + year + origin) ^ 2 + cylinders:displacement:acceleration ,data=cleaned_data )
```

```
# Print the summary of the model
```

```
summary(interaction_model2)
```

```
##
## Call:
## lm(formula = mpg ~ (cylinders + displacement + weight + horsepower +
##   acceleration + year + origin)^2 + cylinders:displacement:acceleration,
##   data = cleaned_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
```

```
## -7.239 -1.410 0.042 1.287 10.821
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -1.995e+01  5.335e+01  -0.374  0.70866
## cylinders      1.694e+01  8.360e+00   2.027  0.04341 *
## displacement  -9.258e-03  2.134e-01  -0.043  0.96541
## weight        -1.023e-02  1.747e-02  -0.586  0.55845
## horsepower     7.150e-01  3.420e-01   2.091  0.03724 *
## acceleration  -1.963e+00  2.298e+00  -0.854  0.39370
## year           6.349e-01  5.950e-01   1.067  0.28663
## origin        -1.695e+01  6.982e+00  -2.427  0.01571 *
## cylinders:displacement -6.392e-02  1.514e-02  -4.222  3.06e-05 ***
## cylinders:weight    3.297e-04  8.737e-04   0.377  0.70610
## cylinders:horsepower  5.506e-03  2.365e-02   0.233  0.81603
## cylinders:acceleration -4.485e-01  2.316e-01  -1.936  0.05362 .
## cylinders:year      -1.475e-01  9.497e-02  -1.553  0.12121
## cylinders:origin     3.199e-01  4.810e-01   0.665  0.50639
## displacement:weight  2.914e-05  1.437e-05   2.027  0.04337 *
## displacement:horsepower  2.391e-05  2.825e-04   0.085  0.93259
## displacement:acceleration -2.906e-02  6.669e-03  -4.358  1.71e-05 ***
## displacement:year     5.145e-03  2.339e-03   2.199  0.02849 *
## displacement:origin   8.656e-03  1.931e-02   0.448  0.65422
## weight:horsepower    -2.050e-05  2.853e-05  -0.719  0.47291
## weight:acceleration   6.191e-04  2.398e-04   2.582  0.01022 *
## weight:year          -1.182e-04  2.089e-04  -0.566  0.57202
## weight:origin        -6.588e-05  1.557e-03  -0.042  0.96627
## horsepower:acceleration -1.084e-02  3.721e-03  -2.912  0.00382 **
## horsepower:year      -7.899e-03  3.871e-03  -2.041  0.04202 *
## horsepower:origin     2.847e-03  2.859e-02   0.100  0.92073
## acceleration:year     5.311e-02  2.497e-02   2.127  0.03408 *
## acceleration:origin   2.724e-01  1.586e-01   1.718  0.08674 .
## year:origin           1.374e-01  7.219e-02   1.903  0.05778 .
## cylinders:displacement:acceleration  3.777e-03  8.589e-04   4.398  1.44e-05 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.629 on 362 degrees of freedom
## Multiple R-squared:  0.895, Adjusted R-squared:  0.8865
## F-statistic: 106.4 on 29 and 362 DF, p-value: < 2.2e-16
```

Interpretation: cylinders:displacement , displacement:acceleration,horsepower:acceleration,horsepower:year ,acceleration:year cylinders:displacement:acceleration are statistically significant

```
# log (X)

interaction_model3 =lm(mpg ~ log(cylinders) + log(displacement) + log(weight) +
  log(acceleration) + log(year) + log(origin),data= cleaned_data )

# Print the summary of the model
summary(interaction_model3)

##
## Call:
## lm(formula = mpg ~ log(cylinders) + log(displacement) + log(weight) +
```

```
##      log(acceleration) + log(year) + log(origin), data = cleaned_data)
##
## Residuals:
##      Min        1Q    Median        3Q        Max
## -9.7712 -2.0217 -0.0756  1.6291 13.0172
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -80.6285    17.6409  -4.571 6.56e-06 ***
## log(cylinders)    1.4934     1.6993   0.879  0.3801
## log(displacement) -1.0393     1.5760  -0.659  0.5100
## log(weight)     -18.6839     1.7994 -10.383 < 2e-16 ***
## log(acceleration)  0.3333     1.1094   0.300  0.7640
## log(year)       58.7365     3.5395  16.594 < 2e-16 ***
## log(origin)      1.3100     0.5169   2.534  0.0117 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 3.143 on 385 degrees of freedom
## Multiple R-squared:  0.8403, Adjusted R-squared:  0.8378
## F-statistic: 337.6 on 6 and 385 DF,  p-value: < 2.2e-16
```

Interpretation: log of weight, year, origin are statistically significant

3 interactions

```
interaction_model4 = lm(mpg ~ (cylinders + displacement + weight + horsepower +
    acceleration + year + origin) ^ 3 ,data= cleaned_data )

# Print the summary of the model
summary(interaction_model4)
```

```
##
## Call:
## lm(formula = mpg ~ (cylinders + displacement + weight + horsepower +
##      acceleration + year + origin)^3, data = cleaned_data)
##
## Residuals:
##      Min        1Q    Median        3Q        Max
## -7.3263 -1.3084 -0.0916  1.2427 10.3972
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)   -2.151e+02  4.506e+02  -0.477  0.633414
## cylinders      3.804e+01  1.132e+02   0.336  0.737101
## displacement  -2.159e-01  2.595e+00  -0.083  0.933729
## weight        3.354e-01  2.376e-01   1.412  0.159037
## horsepower    -5.629e+00  3.435e+00  -1.638  0.102305
## acceleration  -1.253e+01  1.937e+01  -0.647  0.518227
## year          5.025e+00  5.202e+00   0.966  0.334697
## origin       -9.470e+01  9.183e+01  -1.031  0.303204
## cylinders:displacement -8.647e-03  1.680e-01  -0.051  0.958977
## cylinders:weight      1.888e-02  2.613e-02   0.723  0.470493
## cylinders:horsepower  -6.153e-01  6.333e-01  -0.971  0.332017
## cylinders:acceleration -9.031e-01  5.191e+00  -0.174  0.861998
```

```

## cylinders:year          -6.801e-01  1.290e+00  -0.527  0.598503
## cylinders:origin        8.173e+00  1.591e+01   0.514  0.607746
## displacement:weight    -5.486e-04  4.648e-04  -1.180  0.238746
## displacement:horsepower  1.929e-02  9.712e-03   1.986  0.047894 *
## displacement:acceleration -5.727e-02  1.038e-01  -0.552  0.581427
## displacement:year       1.027e-03  3.065e-02   0.034  0.973292
## displacement:origin     5.925e-01  5.692e-01   1.041  0.298704
## weight:horsepower       -5.419e-04  1.008e-03  -0.537  0.591308
## weight:acceleration     -8.123e-03  8.288e-03  -0.980  0.327759
## weight:year             -4.186e-03  2.823e-03  -1.483  0.139001
## weight:origin          -1.260e-01  4.344e-02  -2.901  0.003965 **
## horsepower:acceleration  3.994e-01  9.552e-02   4.181  3.73e-05 ***
## horsepower:year         4.337e-02  4.213e-02   1.030  0.303972
## horsepower:origin       2.643e+00  7.805e-01   3.386  0.000795 ***
## acceleration:year       1.348e-01  2.307e-01   0.584  0.559511
## acceleration:origin     7.782e+00  3.860e+00   2.016  0.044604 *
## year:origin             3.895e-01  1.024e+00   0.380  0.703859
## cylinders:displacement:weight -3.581e-06  7.703e-06  -0.465  0.642339
## cylinders:displacement:horsepower 1.047e-04  3.498e-04   0.299  0.764857
## cylinders:displacement:acceleration 2.952e-03  2.793e-03   1.057  0.291447
## cylinders:displacement:year 3.492e-04  2.309e-03   0.151  0.879857
## cylinders:displacement:origin -6.383e-02  2.110e-02  -3.025  0.002684 **
## cylinders:weight:horsepower -1.572e-05  4.080e-05  -0.385  0.700276
## cylinders:weight:acceleration 2.805e-04  3.855e-04   0.728  0.467370
## cylinders:weight:year     -3.314e-04  3.417e-04  -0.970  0.332837
## cylinders:weight:origin    2.992e-03  2.797e-03   1.070  0.285530
## cylinders:horsepower:acceleration -1.197e-02  7.002e-03  -1.710  0.088301 .
## cylinders:horsepower:year 1.231e-02  8.431e-03   1.461  0.145102
## cylinders:horsepower:origin -5.544e-02  5.930e-02  -0.935  0.350541
## cylinders:acceleration:year 1.158e-02  6.050e-02   0.191  0.848333
## cylinders:acceleration:origin 7.960e-02  4.358e-01   0.183  0.855180
## cylinders:year:origin     -3.052e-02  1.636e-01  -0.187  0.852118
## displacement:weight:horsepower 8.808e-08  3.359e-07   0.262  0.793332
## displacement:weight:acceleration -3.748e-06  6.354e-06  -0.590  0.555689
## displacement:weight:year 8.862e-06  6.045e-06   1.466  0.143610
## displacement:weight:origin -1.919e-05  4.168e-05  -0.460  0.645500
## displacement:horsepower:acceleration 3.820e-05  1.079e-04   0.354  0.723541
## displacement:horsepower:year -2.941e-04  1.242e-04  -2.368  0.018460 *
## displacement:horsepower:origin 3.409e-04  1.859e-03   0.183  0.854575
## displacement:acceleration:year 6.991e-04  1.236e-03   0.566  0.571951
## displacement:acceleration:origin -1.184e-02  1.288e-02  -0.919  0.358578
## displacement:year:origin -2.183e-03  6.107e-03  -0.357  0.720972
## weight:horsepower:acceleration 2.583e-06  1.158e-05   0.223  0.823662
## weight:horsepower:year 9.295e-06  1.195e-05   0.778  0.437395
## weight:horsepower:origin -6.136e-05  9.824e-05  -0.625  0.532667
## weight:acceleration:year 7.719e-05  9.701e-05   0.796  0.426779
## weight:acceleration:origin 1.143e-03  7.779e-04   1.470  0.142583
## weight:year:origin 1.369e-03  4.798e-04   2.854  0.004589 **
## horsepower:acceleration:year -3.915e-03  1.154e-03  -3.394  0.000774 ***
## horsepower:acceleration:origin -4.246e-02  1.074e-02  -3.952  9.49e-05 ***
## horsepower:year:origin -2.164e-02  9.107e-03  -2.376  0.018086 *
## acceleration:year:origin -8.235e-02  4.289e-02  -1.920  0.055720 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

```

```
##
## Residual standard error: 2.441 on 328 degrees of freedom
## Multiple R-squared:  0.9179, Adjusted R-squared:  0.9022
## F-statistic: 58.22 on 63 and 328 DF,  p-value: < 2.2e-16

Few statistically significant interactions are: weight:year:origin
horsepower:acceleration:year
horsepower:acceleration:origin
horsepower:year:origin

# Polynomial for each variable to power of 2

interaction_model4 =lm(mpg ~ poly(cylinders, 2) + poly(displacement,2) + poly(weight,2) +
  poly(acceleration,2) + poly(year,2) + poly(origin,2) ,data= cleaned_data )

# Print the summary of the model
summary(interaction_model4)

##
## Call:
## lm(formula = mpg ~ poly(cylinders, 2) + poly(displacement, 2) +
##     poly(weight, 2) + poly(acceleration, 2) + poly(year, 2) +
##     poly(origin, 2), data = cleaned_data)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -8.3596 -1.7162  0.1344  1.5227 12.7407
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)      23.4459     0.1436 163.278 < 2e-16 ***
## poly(cylinders, 2)1    4.9465    11.0006   0.450  0.65321
## poly(cylinders, 2)2   -4.9683     3.8280  -1.298  0.19512
## poly(displacement, 2)1 -9.0863    17.0170  -0.534  0.59369
## poly(displacement, 2)2  2.7141     6.5631   0.414  0.67945
## poly(weight, 2)1     -97.7070     9.6212 -10.155 < 2e-16 ***
## poly(weight, 2)2      30.0318     4.7046   6.384 5.06e-10 ***
## poly(acceleration, 2)1  5.4236     4.1350   1.312  0.19043
## poly(acceleration, 2)2 11.3861     3.7625   3.026  0.00265 **
## poly(year, 2)1        61.3177     3.2017  19.152 < 2e-16 ***
## poly(year, 2)2        15.0758     3.0049   5.017 8.08e-07 ***
## poly(origin, 2)1       9.1602     4.3412   2.110  0.03551 *
## poly(origin, 2)2      -5.2757     3.3161  -1.591  0.11246
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 2.843 on 379 degrees of freedom
## Multiple R-squared:  0.8714, Adjusted R-squared:  0.8673
## F-statistic: 214 on 12 and 379 DF,  p-value: < 2.2e-16

Interpretation: 2nd degree polynomial of weight, year, accelration are significant

# SQRT

interaction_model5 =lm(mpg ~ sqrt(cylinders) + sqrt(displacement) + sqrt(weight) +
  sqrt(acceleration) + sqrt(year) + sqrt(origin),data= cleaned_data )
```

```
# Print the summary of the model
```

```
summary(interaction_model5)
```

```
##
```

```
## Call:
```

```
## lm(formula = mpg ~ sqrt(cylinders) + sqrt(displacement) + sqrt(weight) +
```

```
##     sqrt(acceleration) + sqrt(year) + sqrt(origin), data = cleaned_data)
```

```
##
```

```
## Residuals:
```

```
##      Min       1Q   Median       3Q      Max
```

```
## -9.5485 -2.0666 -0.0413  1.7072 13.1156
```

```
##
```

```
## Coefficients:
```

```
##              Estimate Std. Error t value Pr(>|t|)
```

```
## (Intercept)   -61.14364     8.06700   -7.579 2.62e-13 ***
```

```
## sqrt(cylinders)  -0.08459     1.54711   -0.055  0.95642
```

```
## sqrt(displacement)  0.16141     0.22959    0.703  0.48244
```

```
## sqrt(weight)    -0.73337     0.06599  -11.114 < 2e-16 ***
```

```
## sqrt(acceleration)  0.65928     0.59803    1.102  0.27097
```

```
## sqrt(year)      13.32503     0.83839   15.894 < 2e-16 ***
```

```
## sqrt(origin)      2.89569     0.75933    3.813  0.00016 ***
```

```
## ---
```

```
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

```
##
```

```
## Residual standard error: 3.233 on 385 degrees of freedom
```

```
## Multiple R-squared:  0.8311, Adjusted R-squared:  0.8284
```

```
## F-statistic: 315.7 on 6 and 385 DF,  p-value: < 2.2e-16
```

Interpretation: Sqrt of weight, year, origin are statistically significant