R Notebook

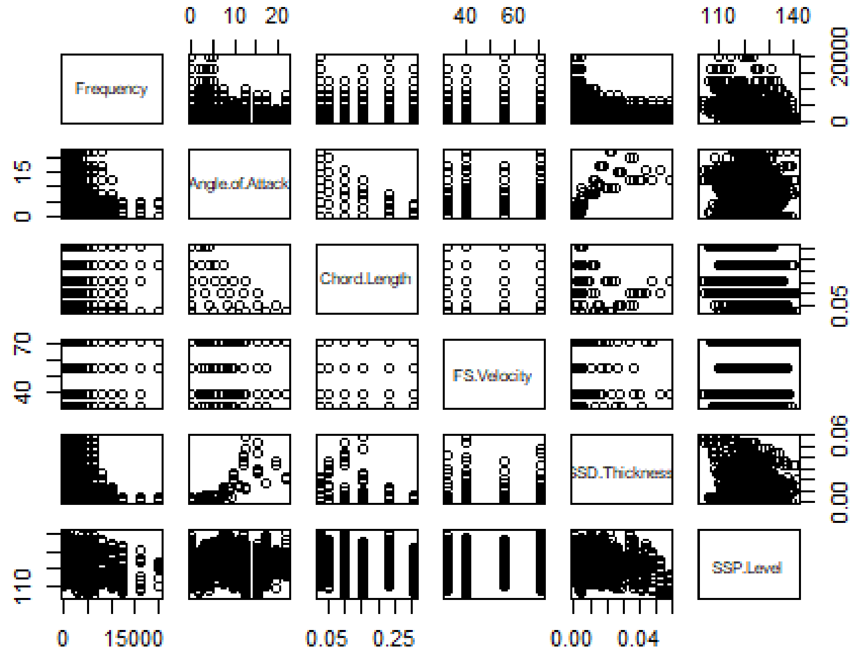
This is an R Markdown Notebook. When you execute code within the notebook, the results appear beneath the code.

Try executing this chunk by clicking the *Run* button within the chunk or by placing your cursor inside it and pressing *Ctrl+Shift+Enter*.

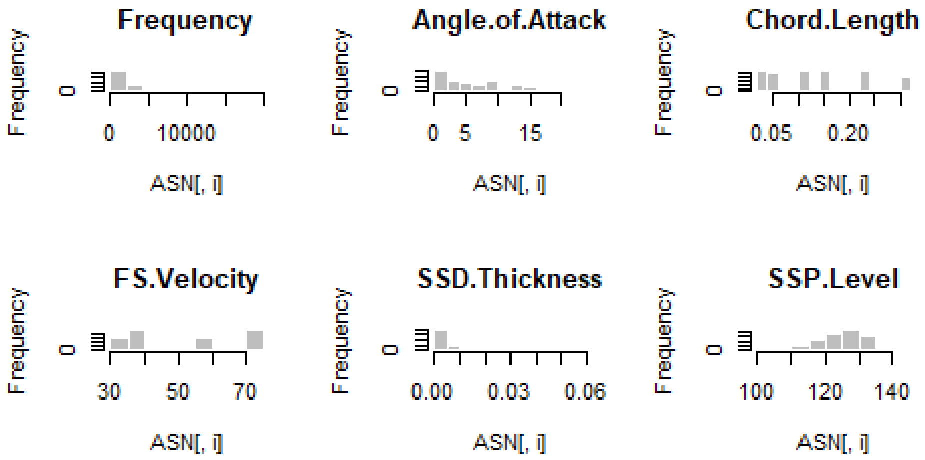
```
# UCI Data sets: Airfoil Self Noise Data Set
# Importing the data Set into R
ASN <- read.csv(file = "C:/Venu/UCI DataSets/Airfoil Self Noise.csv", header
= TRUE,stringsAsFactors = FALSE)
# Exploring the data using summary statistics
summary(ASN)
```

```
##    Frequency     Angle.of.Attack   Chord.Length     FS.Velocity
##  Min.   :  200   Min.   : 0.000   Min.   :0.0254   Min.   :31.70
##  1st Qu.:  800   1st Qu.: 2.000   1st Qu.:0.0508   1st Qu.:39.60
##  Median : 1600   Median : 5.400   Median :0.1016   Median :39.60
##  Mean   : 2886   Mean   : 6.782   Mean   :0.1365   Mean   :50.86
##  3rd Qu.: 4000   3rd Qu.: 9.900   3rd Qu.:0.2286   3rd Qu.:71.30
##  Max.   :20000   Max.   :22.200   Max.   :0.3048   Max.   :71.30
##  SSD.Thickness         SSP.Level
##  Min.   :0.0004007   Min.   :103.4
##  1st Qu.:0.0025351   1st Qu.:120.2
##  Median :0.0049574   Median :125.7
##  Mean   :0.0111399   Mean   :124.8
##  3rd Qu.:0.0155759   3rd Qu.:130.0
##  Max.   :0.0584113   Max.   :141.0
```

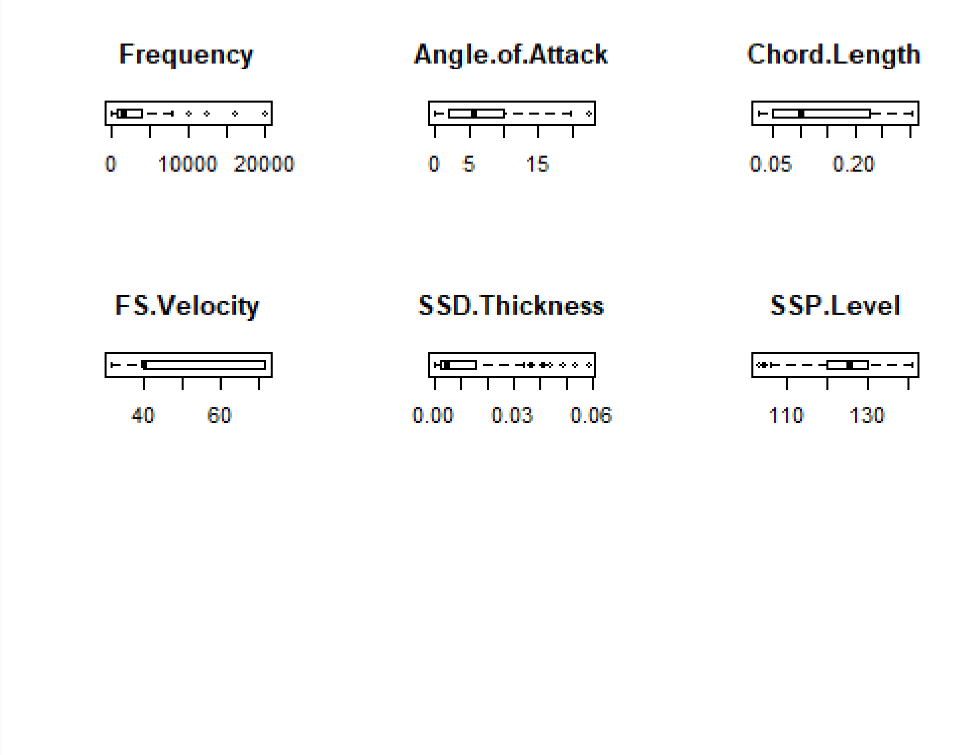
```
# Scatter Plot: Exploring relationships among the variables
plot(ASN)
```



```
# Correlation Analysis: Exploring linear relationships among variables using
Pearson's correlation coerfficient
cor(ASN)

##                   Frequency Angle.of.Attack Chord.Length  FS.Velocity
## Frequency        1.000000000     -0.27276454 -0.003660639  0.133663831
## Angle.of.Attack -0.272764536      1.00000000 -0.504868150  0.058759565
## Chord.Length    -0.003660639     -0.50486815  1.000000000  0.003786629
## FS.Velocity      0.133663831      0.05875957  0.003786629  1.000000000
## SSD.Thickness   -0.230107353      0.75339378 -0.220842431 -0.003974013
## SSP.Level       -0.390711412     -0.15610753 -0.236161512  0.125102801
##                 SSD.Thickness  SSP.Level
## Frequency        -0.230107353 -0.3907114
## Angle.of.Attack   0.753393785 -0.1561075
## Chord.Length     -0.220842431 -0.2361615
## FS.Velocity      -0.003974013  0.1251028
## SSD.Thickness     1.000000000 -0.3126695
## SSP.Level        -0.312669506  1.0000000

attach(ASN)
# Distribution of the variables using histogram

colnames <- dimnames(ASN)[[2]]
par(mfrow = c(3,3))
for (i in 1:6)
  {
    hist(ASN[,i],main = colnames[i],col = "gray",border = "white")
  }
# Box Plots
par(mfrow = c(3,3))
```



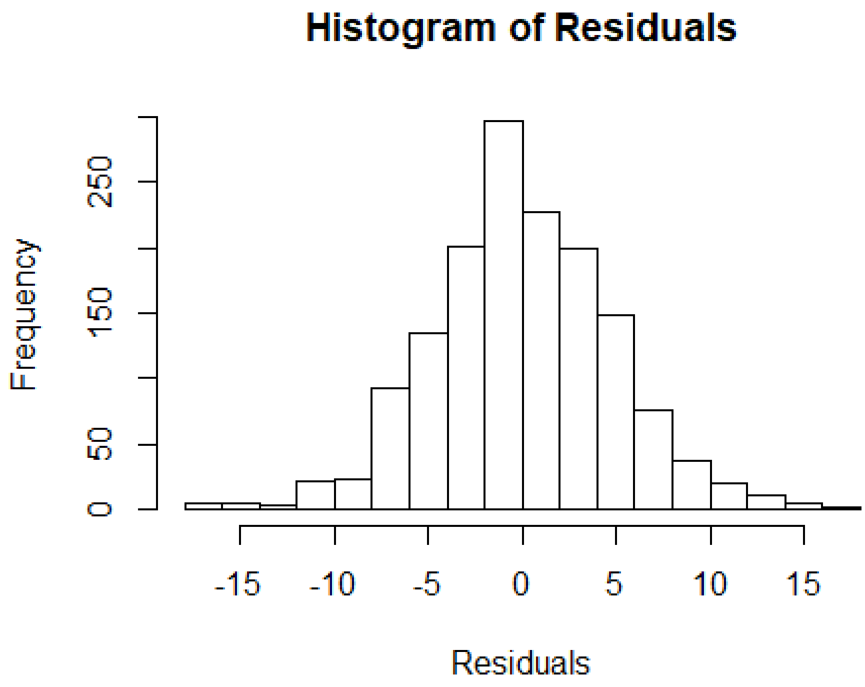
```
for (i in 1:6) {
  boxplot(ASN[,i], horizontal = TRUE, main = colnames[i])
}
```



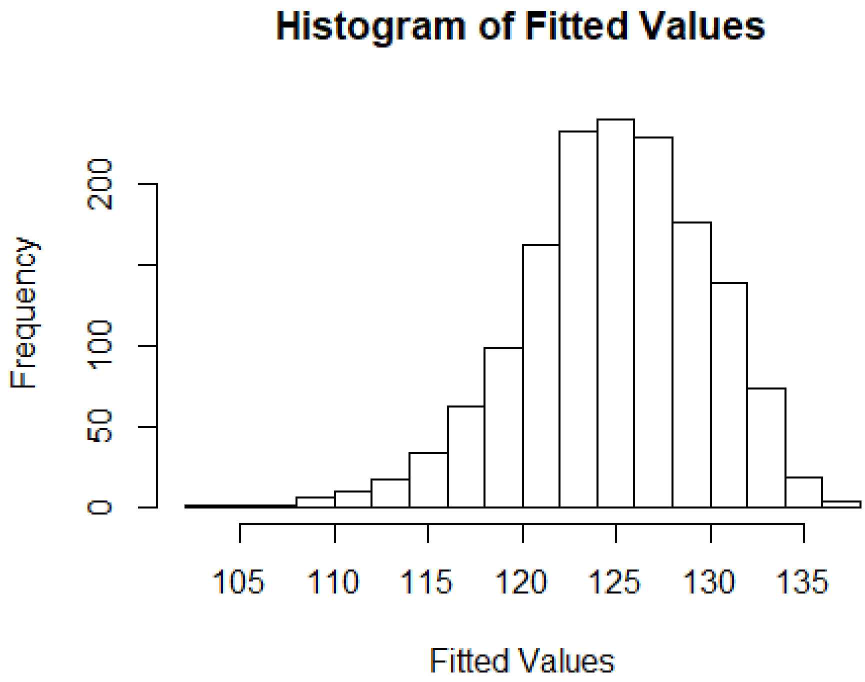
```
# Multiple Linear Regression: SSP noise level as dependent and all others as
independent variables
ASN.Reg <- lm(SSP.Level~.,data = ASN)

# Results of the regression analysis
summary(ASN.Reg)
```

```
##
## Call:
## lm(formula = SSP.Level ~ ., data = ASN)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -17.480  -2.882  -0.209   3.152  16.064
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)      1.328e+02  5.447e-01  243.87   <2e-16 ***
## Frequency       -1.282e-03  4.211e-05  -30.45   <2e-16 ***
## Angle.of.Attack -4.219e-01  3.890e-02  -10.85   <2e-16 ***
## Chord.Length    -3.569e+01  1.630e+00  -21.89   <2e-16 ***
## FS.Velocity      9.985e-02  8.132e-03   12.28   <2e-16 ***
## SSD.Thickness   -1.473e+02  1.501e+01   -9.81   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.809 on 1497 degrees of freedom
## Multiple R-squared:  0.5157, Adjusted R-squared:  0.5141
## F-statistic: 318.8 on 5 and 1497 DF,  p-value: < 2.2e-16

It may observed that all the coefficients (t-tests) are significant as well a
s the overall regression (F-test).

Note that the Multiple R-squared is 51.5% and Adjusted R-squared is about 51.
4%.



ASN.Reg$coefficients

##     (Intercept)       Frequency Angle.of.Attack    Chord.Length     FS.Vel
ocity
##    1.328338e+02   -1.282207e-03   -4.219117e-01   -3.568800e+01    9.98540
4e-02
##   SSD.Thickness
##   -1.473005e+02

par(mfrow=c(1,1))
```

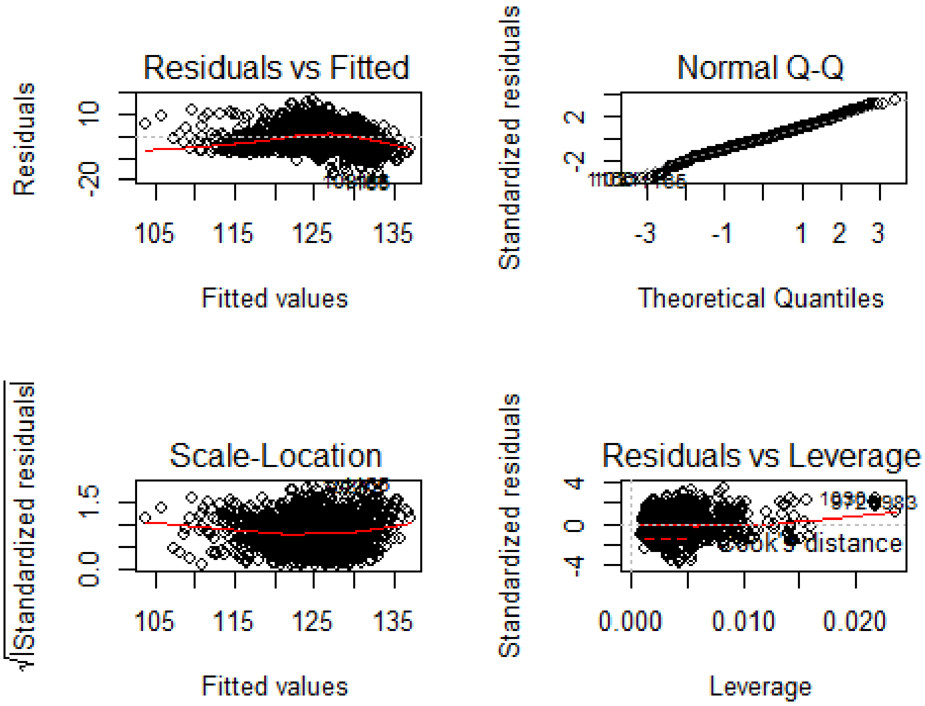
```
# Histogram of residuals
hist(ASN.Reg$residuals,xlab = "Residuals", main = "Histogram of Residuals")
```



```r
# Distribution of fitted value s
hist(ASN.Reg$fitted.values, xlab = "Fitted Values", main = "Histogram of Fitt
ed Values")
```



```r
# Validating Assumptions of Regression Analysis; Normality, Heteroscadasticit
y, Multicollinearity
par(mfrow=c(2,2))
plot(ASN.Reg)
```



```
library(car)

## Loading required package: carData

vif(ASN.Reg)

##       Frequency Angle.of.Attack    Chord.Length     FS.Velocity   SSD.Thic
kness
##        1.144444        3.441658        1.510754        1.041698        2.5
32127
```

It may be noted that above diagrams and table of Variance Inflation Factors:

i) absence of heteroskedasticity,
ii) Normality of Residuals
iii) Absence of multicollinearity

```
# Contructing the confidence intervals for the Regression parameters
confint(ASN.Reg)

##                         2.5 %        97.5 %
## (Intercept)      1.317653e+02  1.339023e+02
## Frequency       -1.364799e-03 -1.199615e-03
## Angle.of.Attack -4.982083e-01 -3.456151e-01
## Chord.Length    -3.888617e+01 -3.248983e+01
## FS.Velocity      8.390221e-02  1.158059e-01
## SSD.Thickness   -1.767525e+02 -1.178485e+02

# Construction of confidence and prediction intervals for the mean value of d
ependent variable
predict (ASN.Reg ,data.frame(Frequency=800,Angle.of.Attack=5.4,Chord.Length=0
.1016,FS.Velocity=39.6,SSD.Thickness=0.0049),interval = "confidence")

##        fit      lwr      upr
## 1 129.1363 128.7473 129.5252

# Construction of prediction interval for a randomly chosen value of the depe
ndent variable
predict (ASN.Reg ,data.frame(Frequency=800,Angle.of.Attack=5.4,Chord.Length=0
.1016,FS.Velocity=39.6,SSD.Thickness=0.0049),interval = "prediction")

##        fit      lwr      upr
## 1 129.1363 119.6954 138.5771

# Regression analysis using interaction of variables
ASN.R1 <- lm(SSP.Level~Frequency+Chord.Length+SSD.Thickness+Frequency:SSD.Thi
ckness, data = ASN)
summary(ASN.R1)

## 
## Call:
## lm(formula = SSP.Level ~ Frequency + Chord.Length + SSD.Thickness + 
##     Frequency:SSD.Thickness, data = ASN)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -20.3311  -3.0231   0.1292   3.2401  15.0356 
## 
## Coefficients:
##                           Estimate Std. Error t value Pr(>|t|)    
## (Intercept)              1.333e+02  3.155e-01 422.493   <2e-16 ***
## Frequency               -7.485e-04  4.664e-05 -16.047   <2e-16 ***
## Chord.Length            -2.439e+01  1.361e+00 -17.918   <2e-16 ***
## SSD.Thickness           -1.221e+02  1.354e+01  -9.016   <2e-16 ***
## Frequency:SSD.Thickness -7.187e-02  4.601e-03 -15.621   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 4.794 on 1498 degrees of freedom
## Multiple R-squared:  0.5184, Adjusted R-squared:  0.5171 
## F-statistic: 403.1 on 4 and 1498 DF,  p-value: < 2.2e-16

It may be noted that using interaction of variables yield a significant regre
ssion results. However,
does not improve the R-squared or Adjusted R-squared.
```

```
# Regression analysis using quadratic functions
ASN.R2 <- lm(SSP.Level~Frequency+I(Frequency^2),data = ASN)
summary(ASN.R2)
```

```
##
## Call:
## lm(formula = SSP.Level ~ Frequency + I(Frequency^2), data = ASN)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -18.470  -4.267   0.086   4.147  17.820
##
## Coefficients:
##                  Estimate Std. Error t value Pr(>|t|)
## (Intercept)     1.283e+02  2.742e-01 467.994  < 2e-16 ***
## Frequency      -1.561e-03  1.262e-04 -12.375  < 2e-16 ***
## I(Frequency^2)  5.649e-08  9.217e-09   6.129 1.13e-09 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.276 on 1500 degrees of freedom
## Multiple R-squared:  0.1734, Adjusted R-squared:  0.1723
## F-statistic: 157.3 on 2 and 1500 DF,  p-value: < 2.2e-16
```

```
ASN.R3 <- lm(SSP.Level~Chord.Length+I(Chord.Length^2),data = ASN)
summary(ASN.R3)
```

```
##
## Call:
## lm(formula = SSP.Level ~ Chord.Length + I(Chord.Length^2), data = ASN)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -21.0417  -4.5202   0.7471   5.2396  16.8241
##
## Coefficients:
##                   Estimate Std. Error t value Pr(>|t|)
## (Intercept)       127.7335     0.4715 270.916  < 2e-16 ***
## Chord.Length      -27.8393     7.4324  -3.746 0.000187 ***
## I(Chord.Length^2)  32.9997    22.7930   1.448 0.147882
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.703 on 1500 degrees of freedom
## Multiple R-squared:  0.05709,    Adjusted R-squared:  0.05583
## F-statistic: 45.41 on 2 and 1500 DF,  p-value: < 2.2e-16
```

```
ASN.R4 <- lm(SSP.Level~SSD.Thickness+I(SSD.Thickness^2),data = ASN)
summary(ASN.R4)
```

```
## 
## Call:
## lm(formula = SSP.Level ~ SSD.Thickness + I(SSD.Thickness^2), 
##     data = ASN)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -19.8203  -4.5623   0.7384   4.7406  18.6726 
## 
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)    
## (Intercept)          126.2263     0.2793 451.925   <2e-16 ***
## SSD.Thickness        -66.6654    40.1074  -1.662   0.0967 .  
## I(SSD.Thickness^2) -2181.3511   851.3100  -2.562   0.0105 *  
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 6.543 on 1500 degrees of freedom
## Multiple R-squared:  0.1017, Adjusted R-squared:  0.1005 
## F-statistic:  84.9 on 2 and 1500 DF,  p-value: < 2.2e-16
```

```r
# Regression analysis using higher order polynomials functions (Non-linear functions)
ASN.R5 <- lm(SSP.Level~poly(Frequency,5),data = ASN)
summary(ASN.R5)
```

```
## 
## Call:
## lm(formula = SSP.Level ~ poly(Frequency, 5), data = ASN)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -18.7596  -4.0277   0.0768   3.8827  19.2372 
## 
## Coefficients:
##                      Estimate Std. Error t value Pr(>|t|)    
## (Intercept)          124.8359     0.1604 778.512  < 2e-16 ***
## poly(Frequency, 5)1 -104.4613     6.2166 -16.804  < 2e-16 ***
## poly(Frequency, 5)2   38.4702     6.2166   6.188 7.84e-10 ***
## poly(Frequency, 5)3    1.2528     6.2166   0.202 0.840313    
## poly(Frequency, 5)4  -21.0053     6.2166  -3.379 0.000746 ***
## poly(Frequency, 5)5   28.1765     6.2166   4.532 6.29e-06 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 6.217 on 1497 degrees of freedom
## Multiple R-squared:  0.1907, Adjusted R-squared:  0.188 
## F-statistic: 70.53 on 5 and 1497 DF,  p-value: < 2.2e-16
```

```r
ASN.R6 <- lm(SSP.Level~poly(Chord.Length,5),data = ASN)
summary(ASN.R6)
```

```
##
## Call:
## lm(formula = SSP.Level ~ poly(Chord.Length, 5), data = ASN)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -21.7224  -4.5580   0.7475   5.2123  15.8530
##
## Coefficients:
##                        Estimate Std. Error t value Pr(>|t|)
## (Intercept)             124.836      0.172 725.882  < 2e-16 ***
## poly(Chord.Length, 5)1  -63.141      6.667  -9.470  < 2e-16 ***
## poly(Chord.Length, 5)2    9.705      6.667   1.456  0.14571
## poly(Chord.Length, 5)3   -7.850      6.667  -1.177  0.23923
## poly(Chord.Length, 5)4  -21.541      6.667  -3.231  0.00126 **
## poly(Chord.Length, 5)5  -18.136      6.667  -2.720  0.00660 **
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.667 on 1497 degrees of freedom
## Multiple R-squared:  0.06904,    Adjusted R-squared:  0.06594
## F-statistic: 22.21 on 5 and 1497 DF,  p-value: < 2.2e-16
```

```r
ASN.R7 <- lm(SSP.Level~log(Frequency),data = ASN)
summary(ASN.R7)
```

```
##
## Call:
## lm(formula = SSP.Level ~ log(Frequency), data = ASN)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -19.6827  -4.3373   0.2065   4.4321  16.6844
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)    141.5836     1.1517   122.9   <2e-16 ***
## log(Frequency)  -2.2554     0.1535   -14.7   <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 6.452 on 1501 degrees of freedom
## Multiple R-squared:  0.1258, Adjusted R-squared:  0.1252
## F-statistic:   216 on 1 and 1501 DF,  p-value: < 2.2e-16
```

```
It is observed that higher order polynomials in different variables fail to i
mprove the value of R-squared or
```

```
Adjusted R-Squared. Hence, it may be concluded that the multiple linear regression provides the best model among the
alternatives tried with Prediction accuracy of 51.4%.
```