# R Notebook on Linear Regression Lab

Code

Hide

```
install.packages('ISLR')
```

```
WARNING: Rtools is required to build R packages but is not currently installed. Please download
and install the appropriate version of Rtools before proceeding:

https://cran.rstudio.com/bin/windows/Rtools/
Installing package into ‘C:/Users/91771/AppData/Local/R/win-library/4.2’
(as ‘lib’ is unspecified)
trying URL 'https://cran.rstudio.com/bin/windows/contrib/4.2/ISLR_1.4.zip'
Content type 'application/zip' length 2924080 bytes (2.8 MB)
downloaded 2.8 MB
```

```
package ‘ISLR’ successfully unpacked and MD5 sums checked

The downloaded binary packages are in
    C:\Users\91771\AppData\Local\Temp\RtmpSyQPmO\downloaded_packages
```

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```
#importing the packages
library(ISLR)
library(MASS)
```

# Simple Linear Regression

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```
#previewing boston dataset and fixing
fix(Boston)
```

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```
names(Boston)
```

```
 [1] "crim"    "zn"      "indus"   "chas"    "nox"     "rm"
 [7] "age"     "dis"     "rad"     "tax"     "ptratio" "black"
[13] "lstat"   "medv"
```

Hide

```
#attaching the dataset and fitting the linear model
attach(Boston)
```

```
The following objects are masked from Boston (pos = 5):

    age, black, chas, crim, dis, indus, lstat, medv, nox, ptratio, rad, rm, tax, zn
```

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```
lm.fit = lm(medv~lstat,data=Boston)
```

Hide

```
summary(lm.fit)
```

```

Call:
lm(formula = medv ~ lstat, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max
-15.168  -3.990  -1.318   2.034  24.500

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 34.55384    0.56263   61.41   <2e-16 ***
lstat       -0.95005    0.03873  -24.53   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.216 on 504 degrees of freedom
Multiple R-squared:  0.5441,    Adjusted R-squared:  0.5432
F-statistic: 601.6 on 1 and 504 DF,  p-value: < 2.2e-16
```

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```
names(lm.fit)
```

```
 [1] "coefficients"  "residuals"     "effects"       "rank"          "fitted.values" "assign"
 [7] "qr"            "df.residual"   "xlevels"       "call"          "terms"         "model"
```

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```
coef(lm.fit)
```

```
(Intercept)       lstat
 34.5538409  -0.9500494
```

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```
confint(lm.fit)
```

```
               2.5 %     97.5 %
(Intercept) 33.448457 35.6592247
lstat       -1.026148 -0.8739505
```

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```
predict(lm.fit,data.frame(lstat=(c(5,10,15))), interval="confidence") #confidence intervals
```

```
       fit      lwr      upr
1 29.80359 29.00741 30.59978
2 25.05335 24.47413 25.63256
3 20.30310 19.73159 20.87461
```

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```
predict(lm.fit,data.frame(lstat=(c(5,10,15))), interval="prediction") #prediction intervals
```

```
       fit       lwr      upr
1 29.80359 17.565675 42.04151
2 25.05335 12.827626 37.27907
3 20.30310  8.077742 32.52846
```

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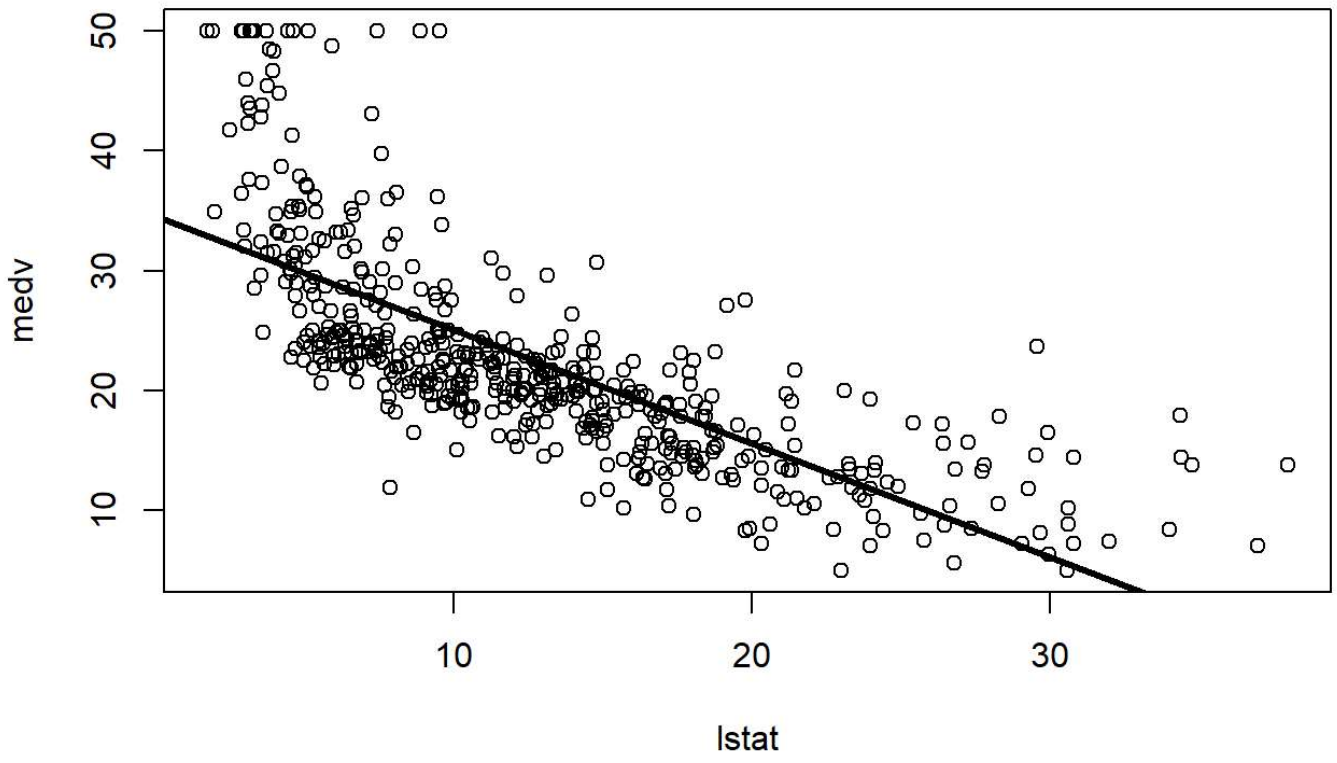
```
plot(lstat,medv) #plotting the variables
abline(lm.fit,lwd=3) #generating regression lines
```

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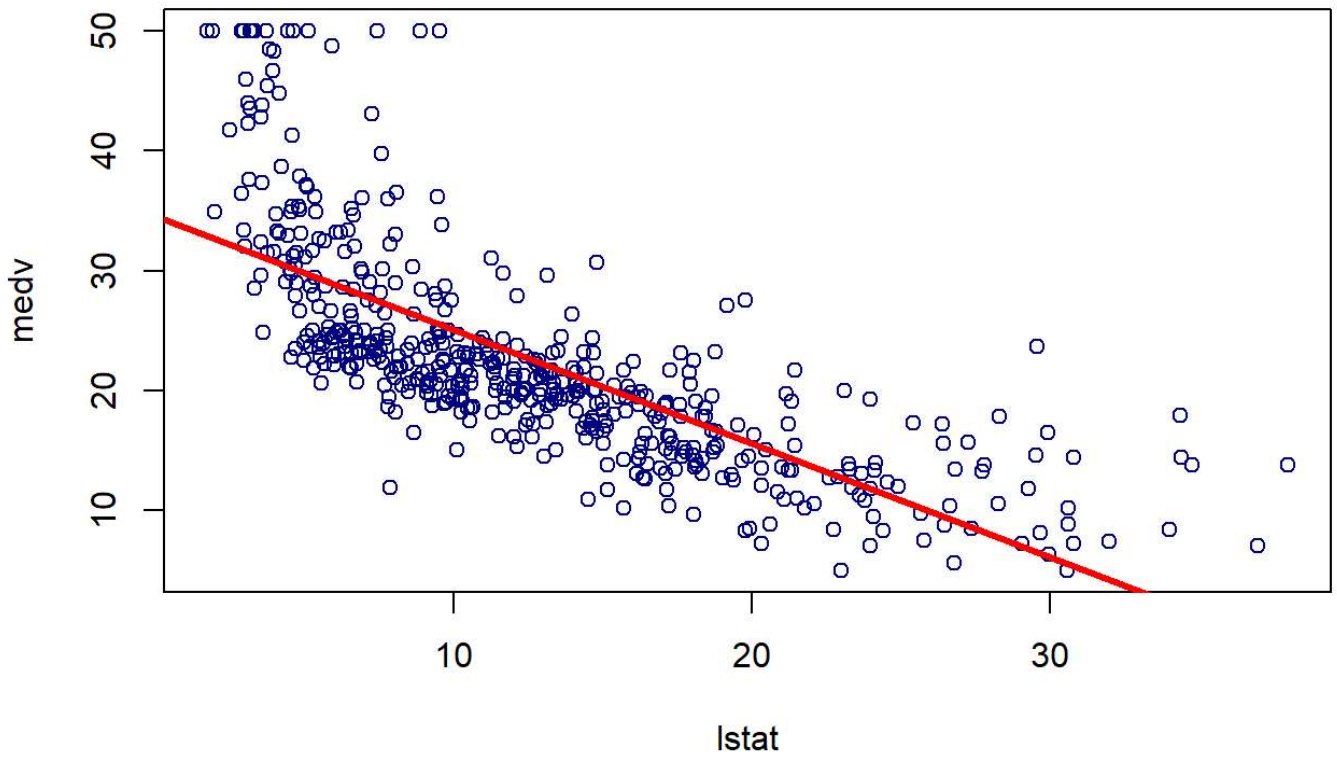
```
#making it colourfull
plot(lstat,medv,col='navy')
abline(lm.fit,lwd=3,col='red')
```

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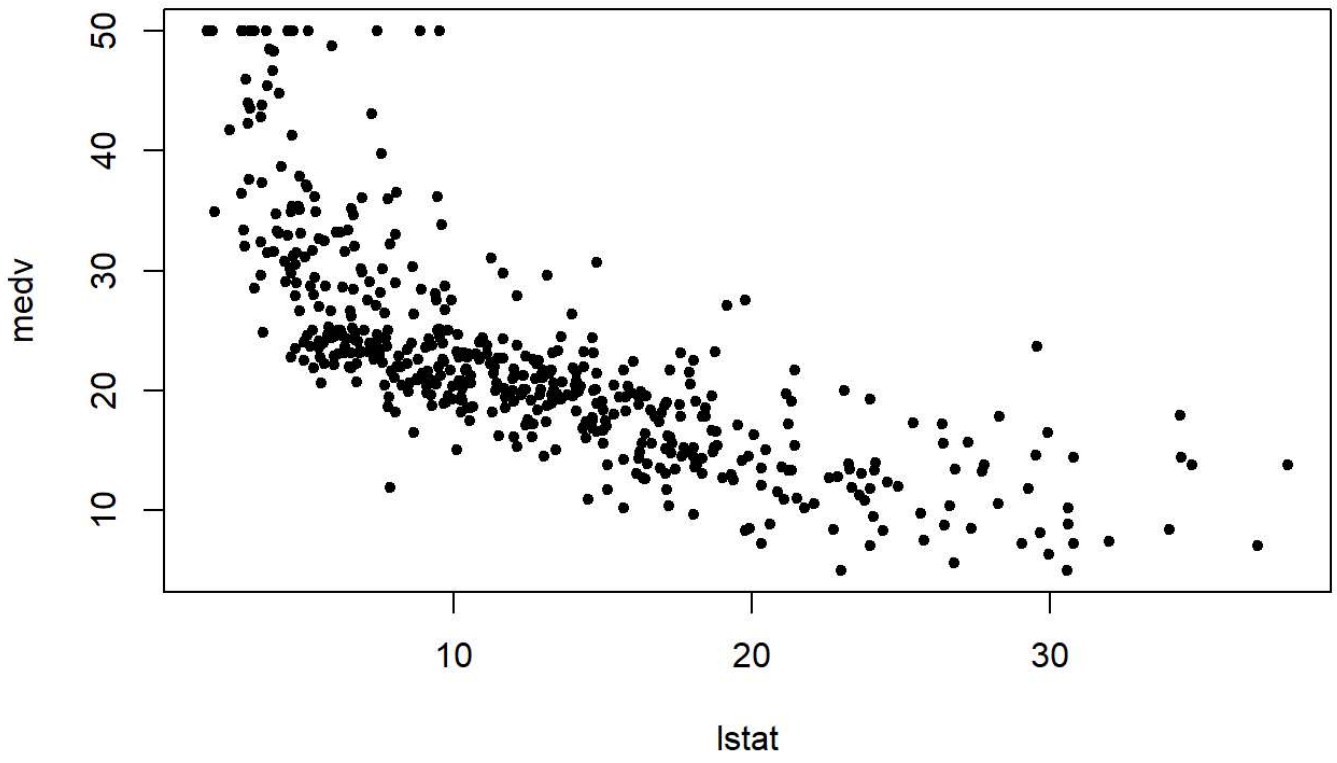
```
#process to change shapes in the plot
plot(lstat,medv,pch=20)
```

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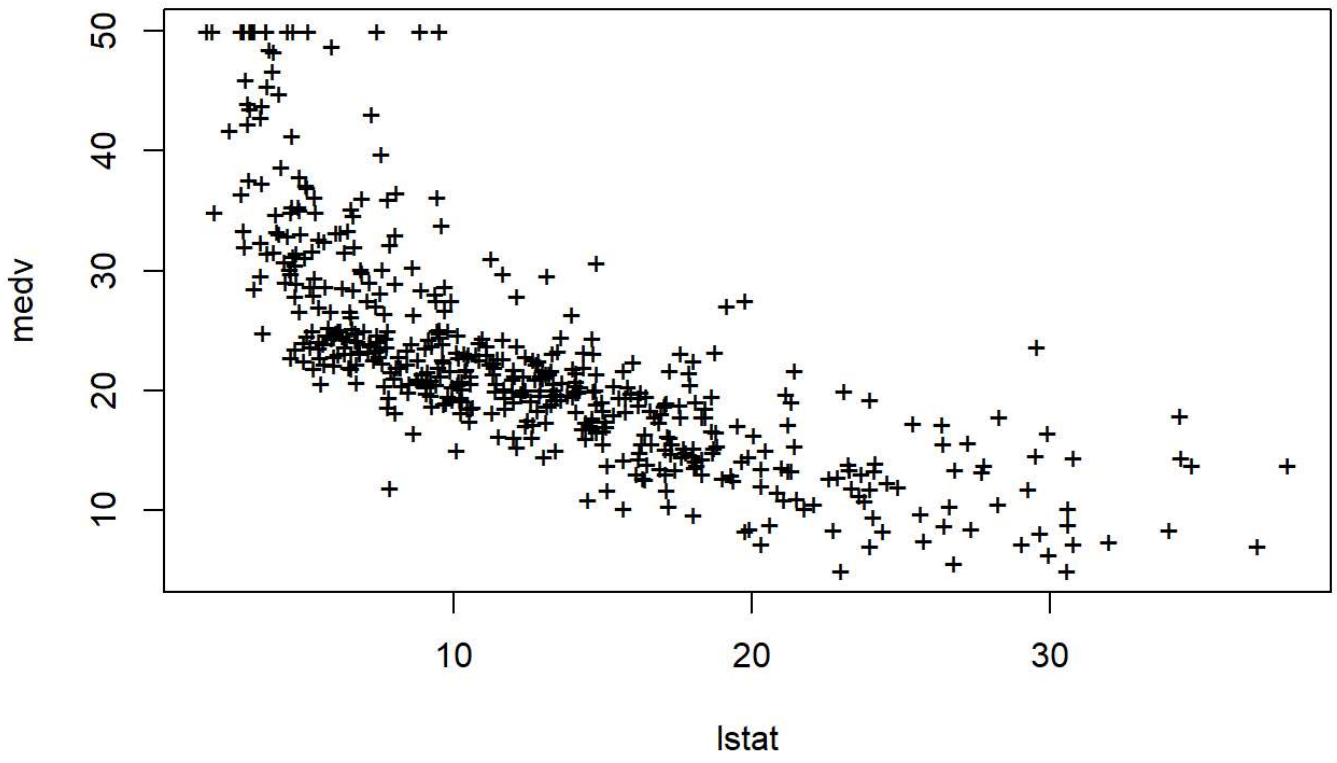
```
#another kind of shape
plot(lstat,medv,pch="+")
```

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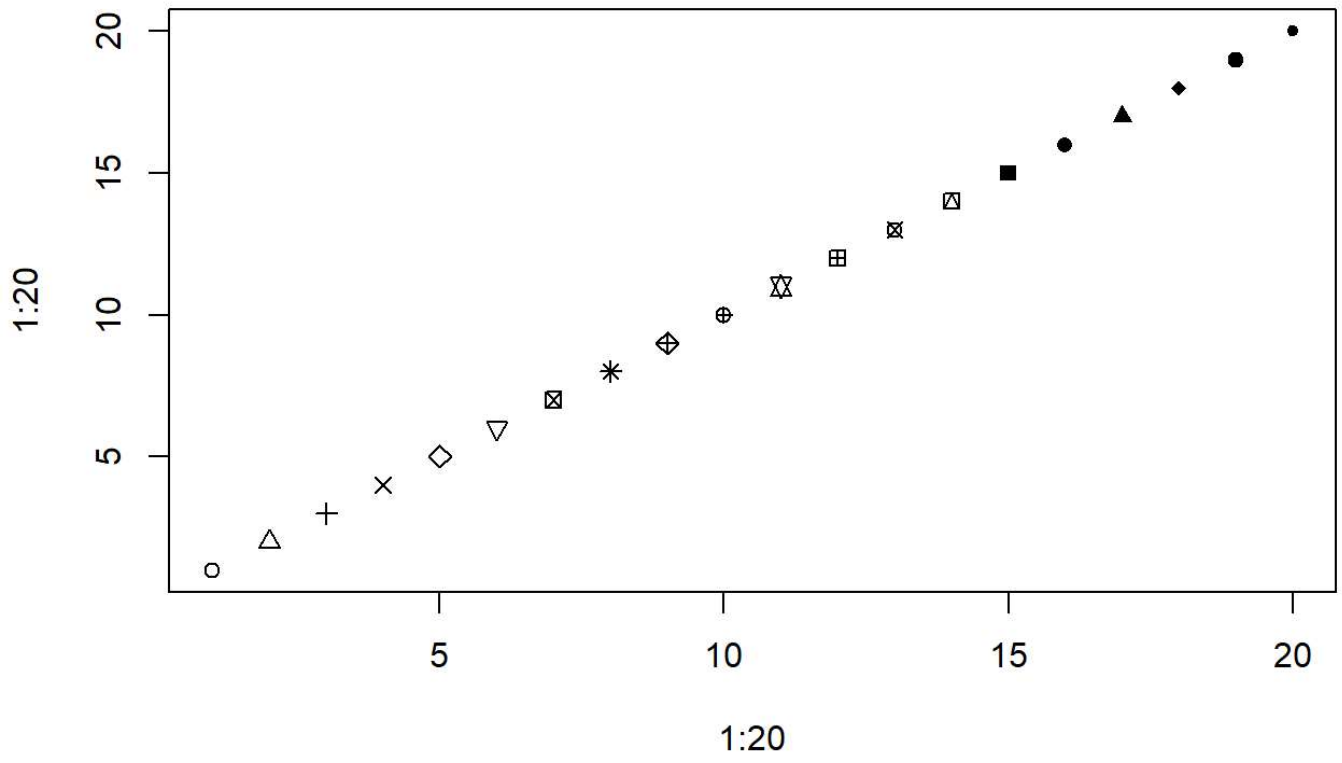
```
#'pch' is the command
plot(1:20,1:20,pch=1:20)
```

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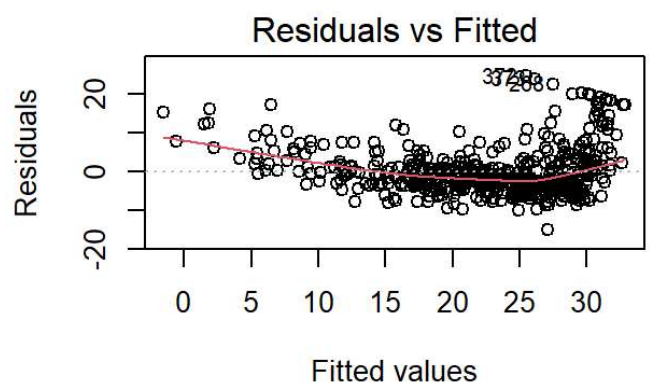
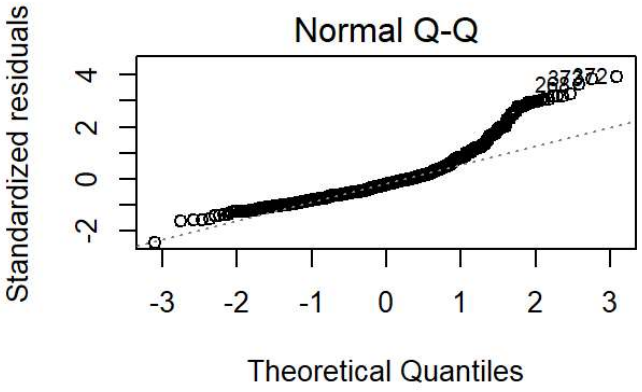
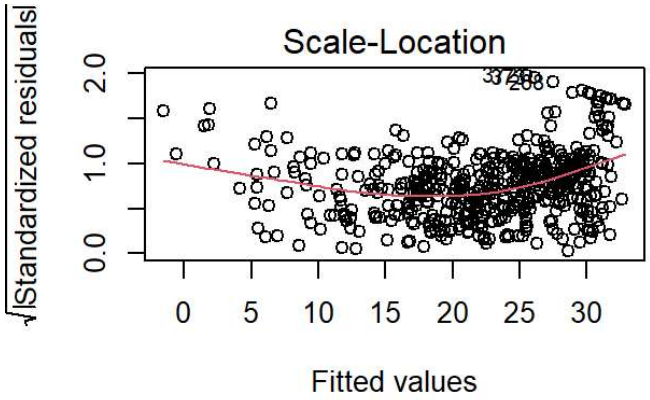
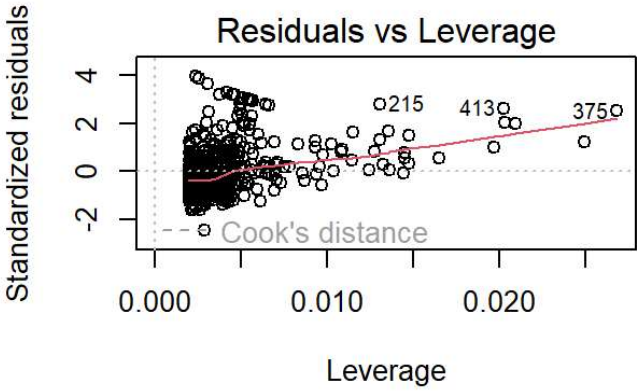
```
#dividing the plotting in 2x2 grids using 'par(mfrow=)'
par(mfrow=c(2,2))
plot(lm.fit)
```

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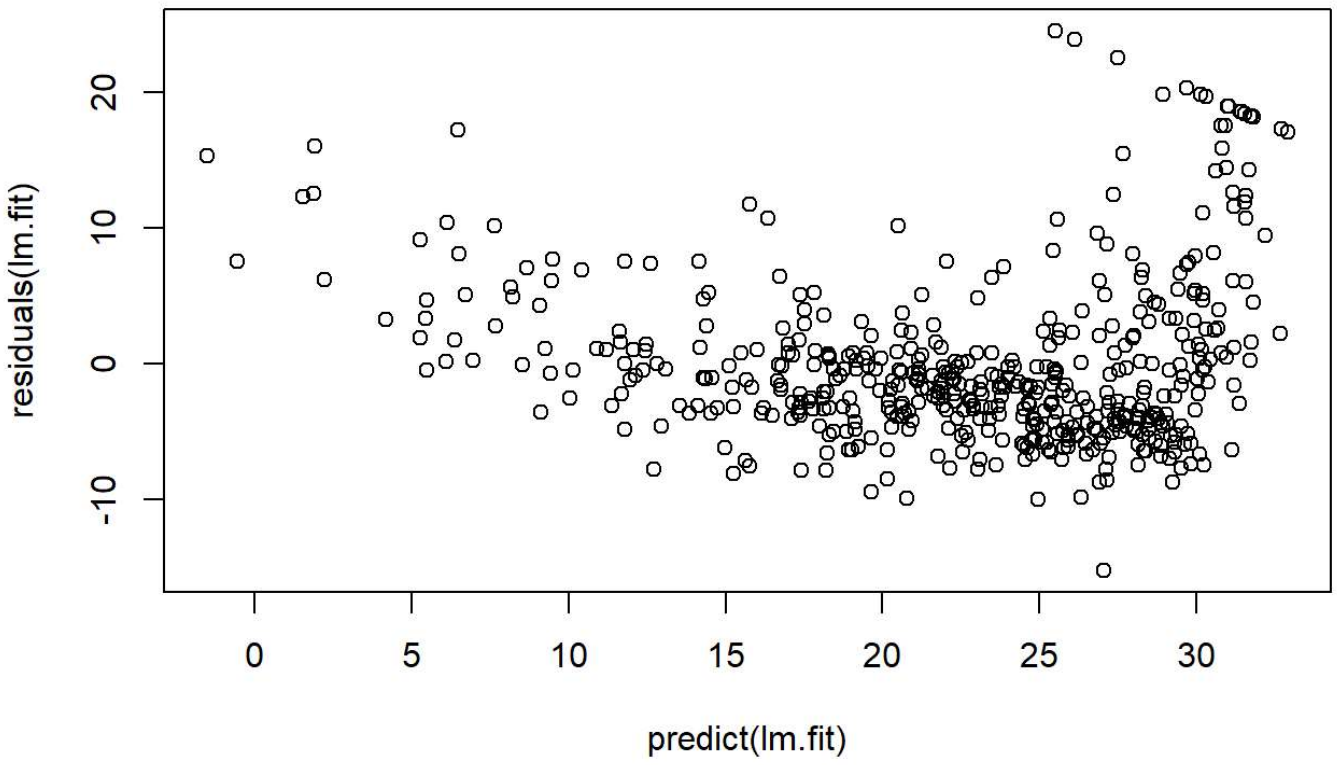
```
#computing residual plot
plot(predict(lm.fit), residuals(lm.fit))
```

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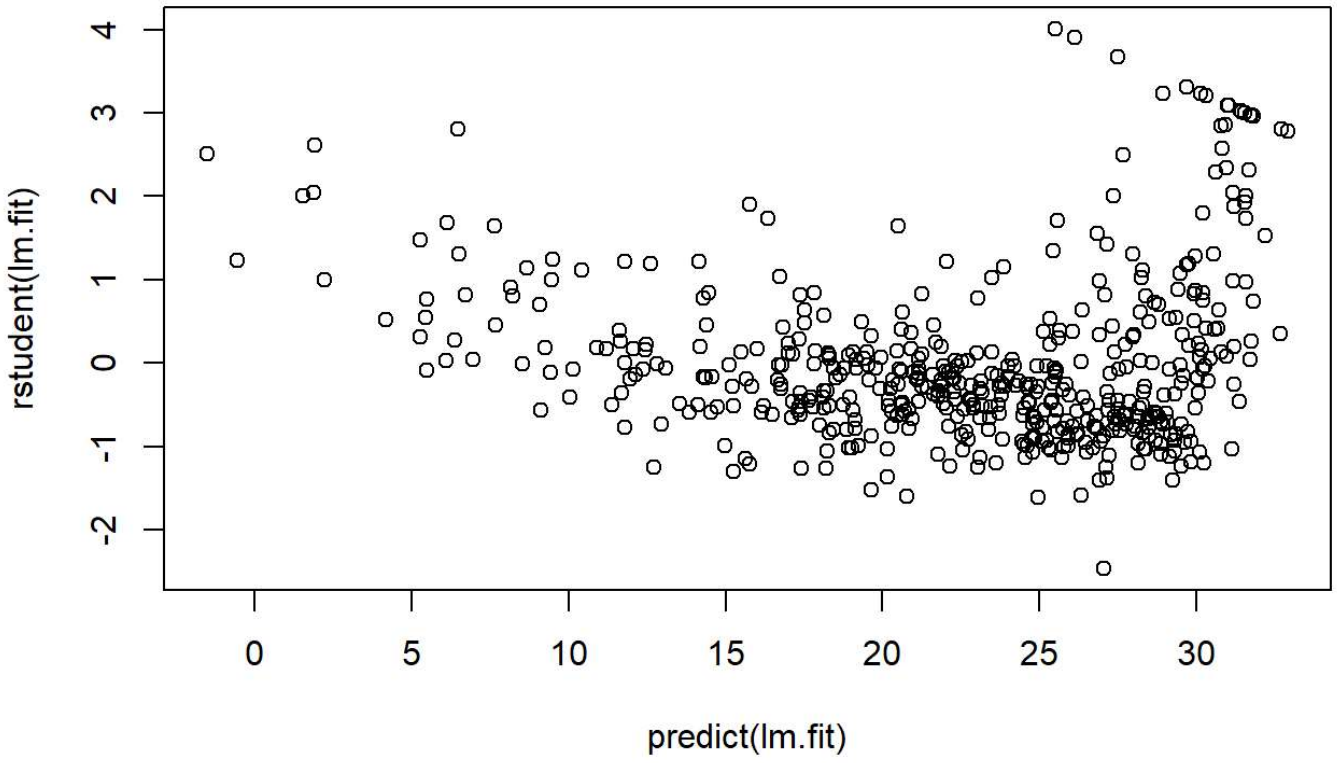
```
#stundentized residuals=quotient resulting from the division of a residual by an estimate of its standard deviation.
plot(predict(lm.fit), rstudent(lm.fit))
```

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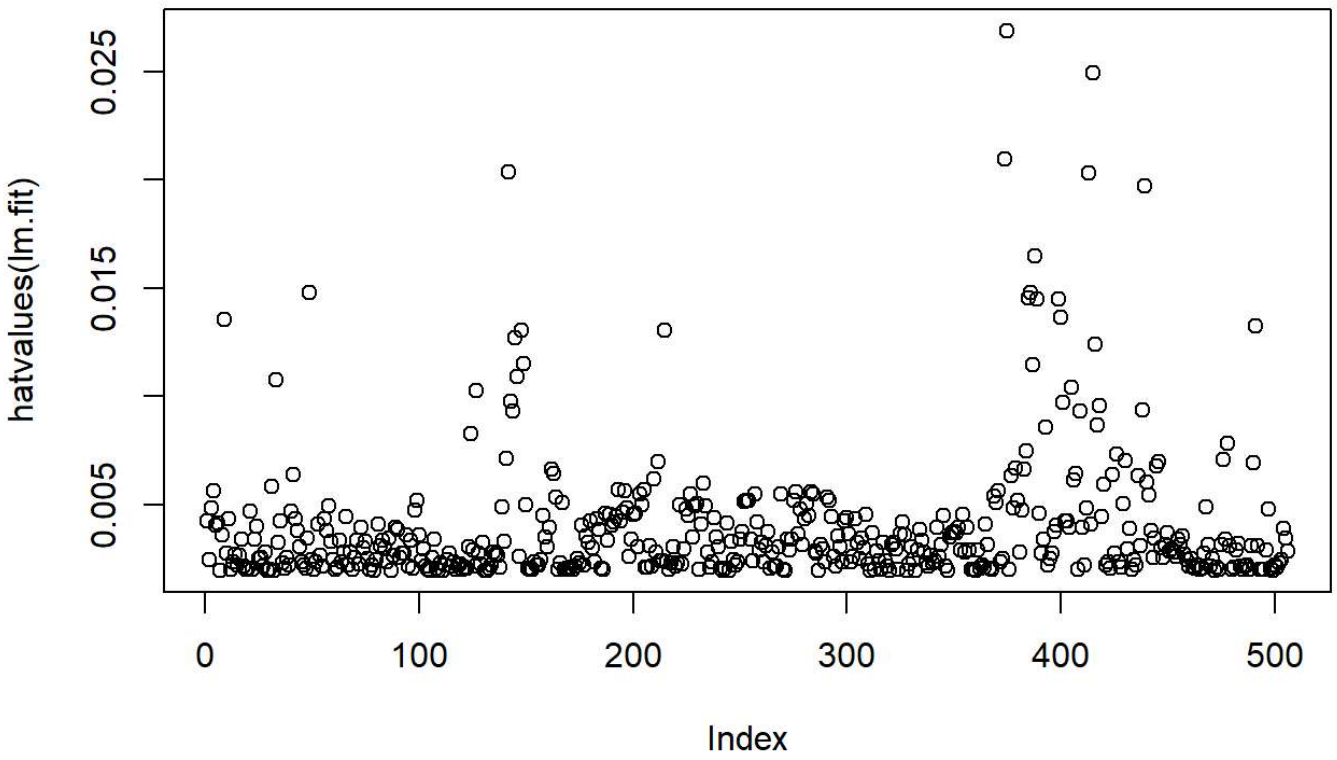
```
#a suite of functions that can be used to compute some of the regression (leave-one-out deletio
n) diagnostics, for the VGLM class
plot(hatvalues(lm.fit))
```

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```
#identifying largest element of a factor
which.max(hatvalues(lm.fit))
```

```
375
375
```

# Multiple Linear Regression

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```
#fitting the multiple linear model
lm.fit=lm(medv~lstat+age,data=Boston)
summary(lm.fit)
```

```
Call:
lm(formula = medv ~ lstat + age, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max
-15.981  -3.978  -1.283   1.968  23.158

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept) 33.22276    0.73085  45.458  < 2e-16 ***
lstat       -1.03207    0.04819 -21.416  < 2e-16 ***
age          0.03454    0.01223   2.826  0.00491 **
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.173 on 503 degrees of freedom
Multiple R-squared:  0.5513,    Adjusted R-squared:  0.5495
F-statistic:   309 on 2 and 503 DF,  p-value: < 2.2e-16
```

Hide

```
#fitting all predictors to output variable using
lm.fit=lm(medv~.,data=Boston)
summary(lm.fit)
```

```
Call:
lm(formula = medv ~ ., data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max
-15.595  -2.730  -0.518   1.777  26.199

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  3.646e+01  5.103e+00   7.144 3.28e-12 ***
crim        -1.080e-01  3.286e-02  -3.287 0.001087 **
zn           4.642e-02  1.373e-02   3.382 0.000778 ***
indus        2.056e-02  6.150e-02   0.334 0.738288
chas         2.687e+00  8.616e-01   3.118 0.001925 **
nox         -1.777e+01  3.820e+00  -4.651 4.25e-06 ***
rm           3.810e+00  4.179e-01   9.116  < 2e-16 ***
age          6.922e-04  1.321e-02   0.052 0.958229
dis         -1.476e+00  1.995e-01  -7.398 6.01e-13 ***
rad          3.060e-01  6.635e-02   4.613 5.07e-06 ***
tax         -1.233e-02  3.760e-03  -3.280 0.001112 **
ptratio     -9.527e-01  1.308e-01  -7.283 1.31e-12 ***
black        9.312e-03  2.686e-03   3.467 0.000573 ***
lstat       -5.248e-01  5.072e-02 -10.347  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.745 on 492 degrees of freedom
Multiple R-squared:  0.7406,    Adjusted R-squared:  0.7338
F-statistic: 108.1 on 13 and 492 DF,  p-value: < 2.2e-16
```

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```
#importing Companion to Applied Regression package
library(car)
```

Hide

```
#variance inflation
vif(lm.fit)
```

```
    crim       zn    indus     chas      nox       rm      age      dis      rad      tax  ptrat
io    black    lstat
1.792192 2.298758 3.991596 1.073995 4.393720 1.933744 3.100826 3.955945 7.484496 9.008554 1.7990
84 1.348521 2.941491
```

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```
#except age all predictors will show
lm.fit1=lm(medv~.-age,data=Boston)
summary(lm.fit1)
```

```

Call:
lm(formula = medv ~ . - age, data = Boston)

Residuals:
     Min       1Q   Median       3Q      Max 
-15.6054  -2.7313  -0.5188   1.7601  26.2243 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept)  36.436927   5.080119   7.172 2.72e-12 ***
crim         -0.108006   0.032832  -3.290 0.001075 ** 
zn            0.046334   0.013613   3.404 0.000719 ***
indus         0.020562   0.061433   0.335 0.737989    
chas          2.689026   0.859598   3.128 0.001863 ** 
nox         -17.713540   3.679308  -4.814 1.97e-06 ***
rm            3.814394   0.408480   9.338  < 2e-16 ***
dis          -1.478612   0.190611  -7.757 5.03e-14 ***
rad           0.305786   0.066089   4.627 4.75e-06 ***
tax          -0.012329   0.003755  -3.283 0.001099 ** 
ptratio      -0.952211   0.130294  -7.308 1.10e-12 ***
black         0.009321   0.002678   3.481 0.000544 ***
lstat        -0.523852   0.047625 -10.999  < 2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 4.74 on 493 degrees of freedom
Multiple R-squared:  0.7406,    Adjusted R-squared:  0.7343 
F-statistic: 117.3 on 12 and 493 DF,  p-value: < 2.2e-16
```

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```
#alternately: lm.fit1=update(lm.fit, ~.-age)
```

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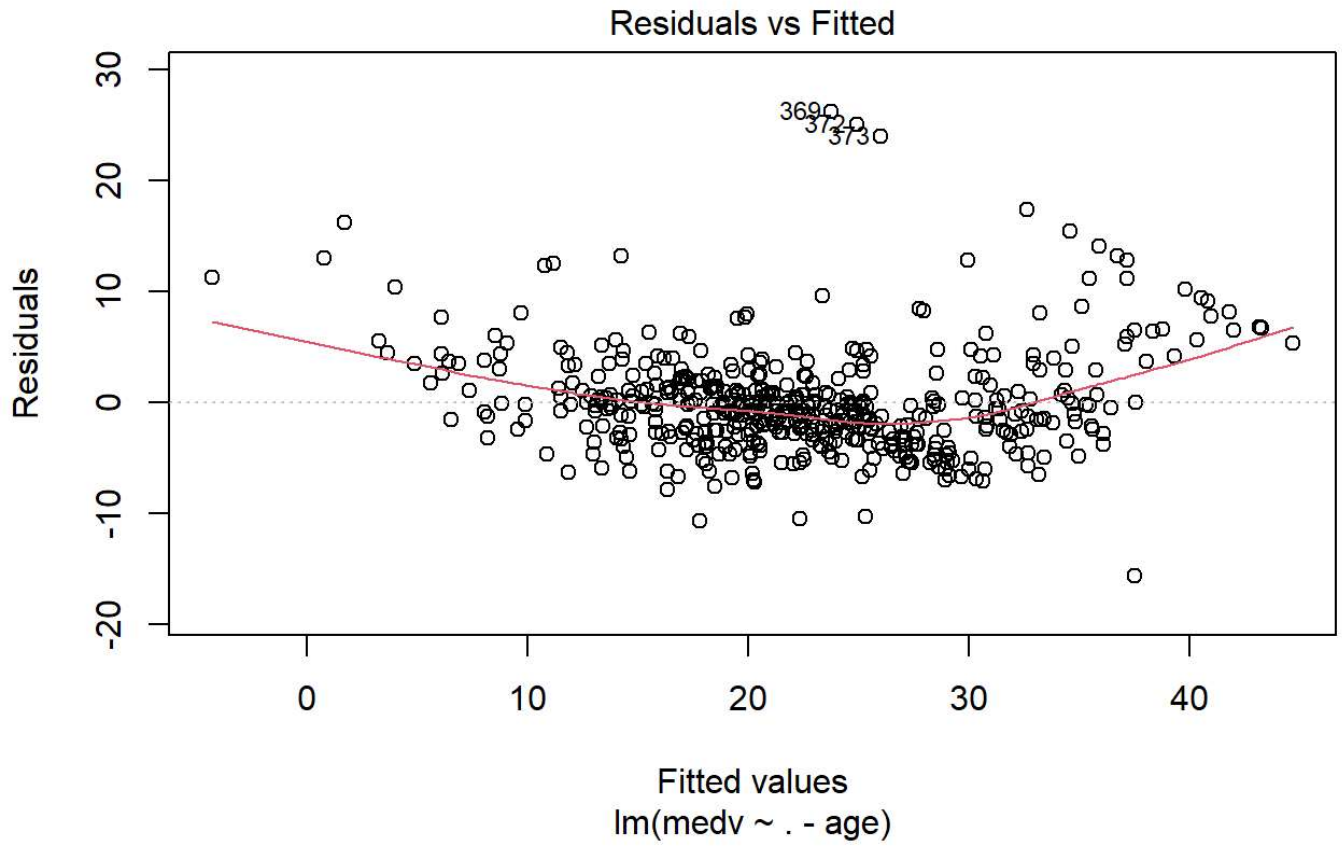
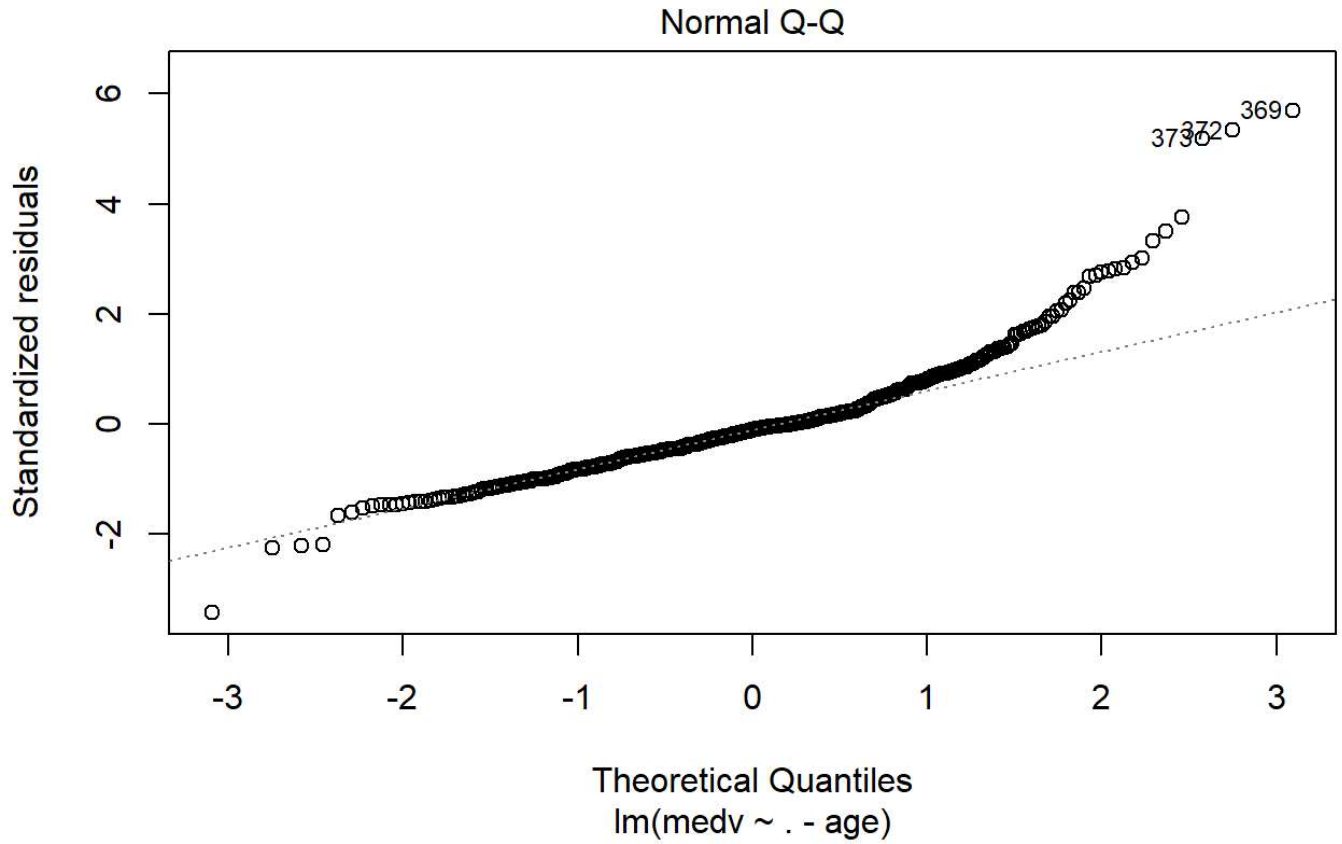
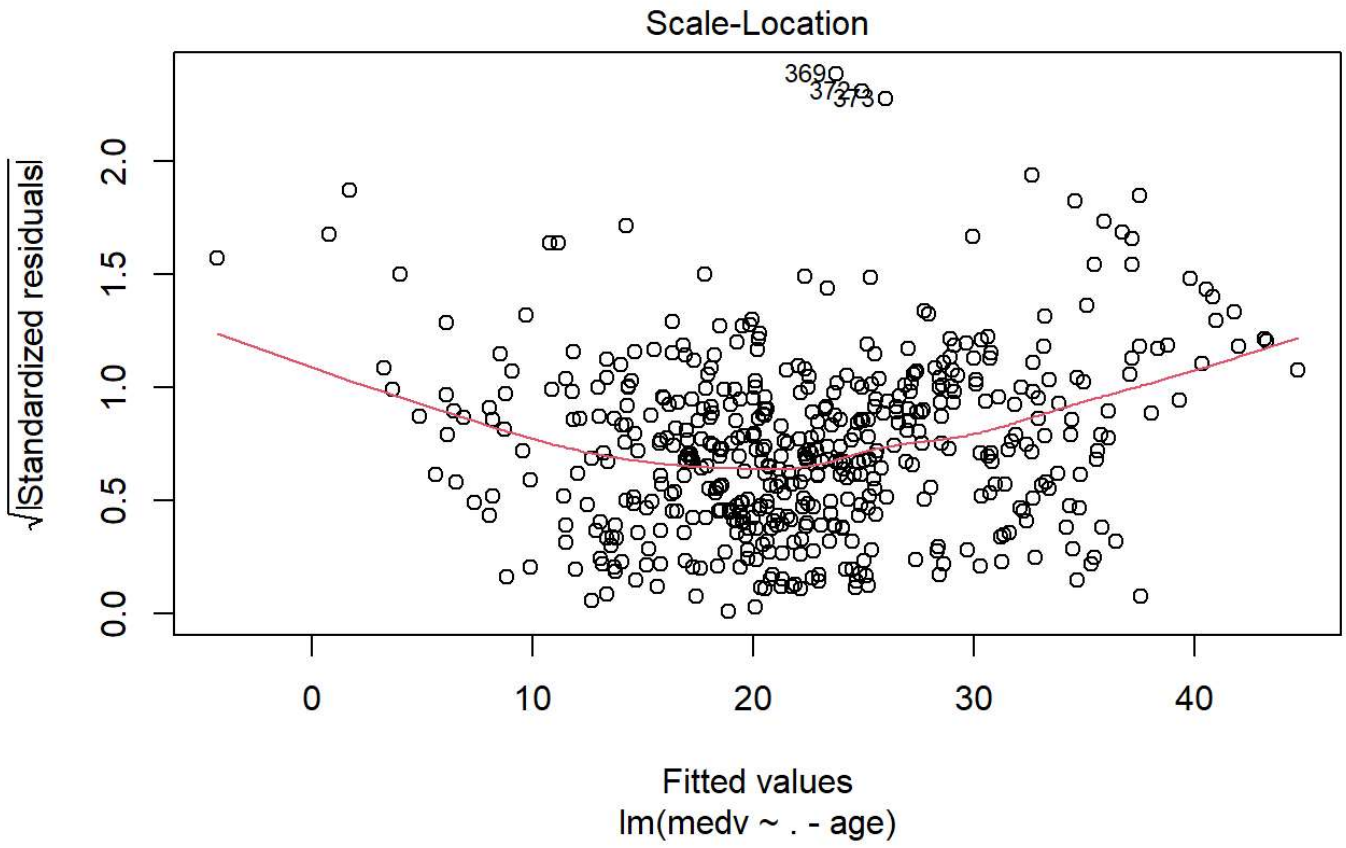
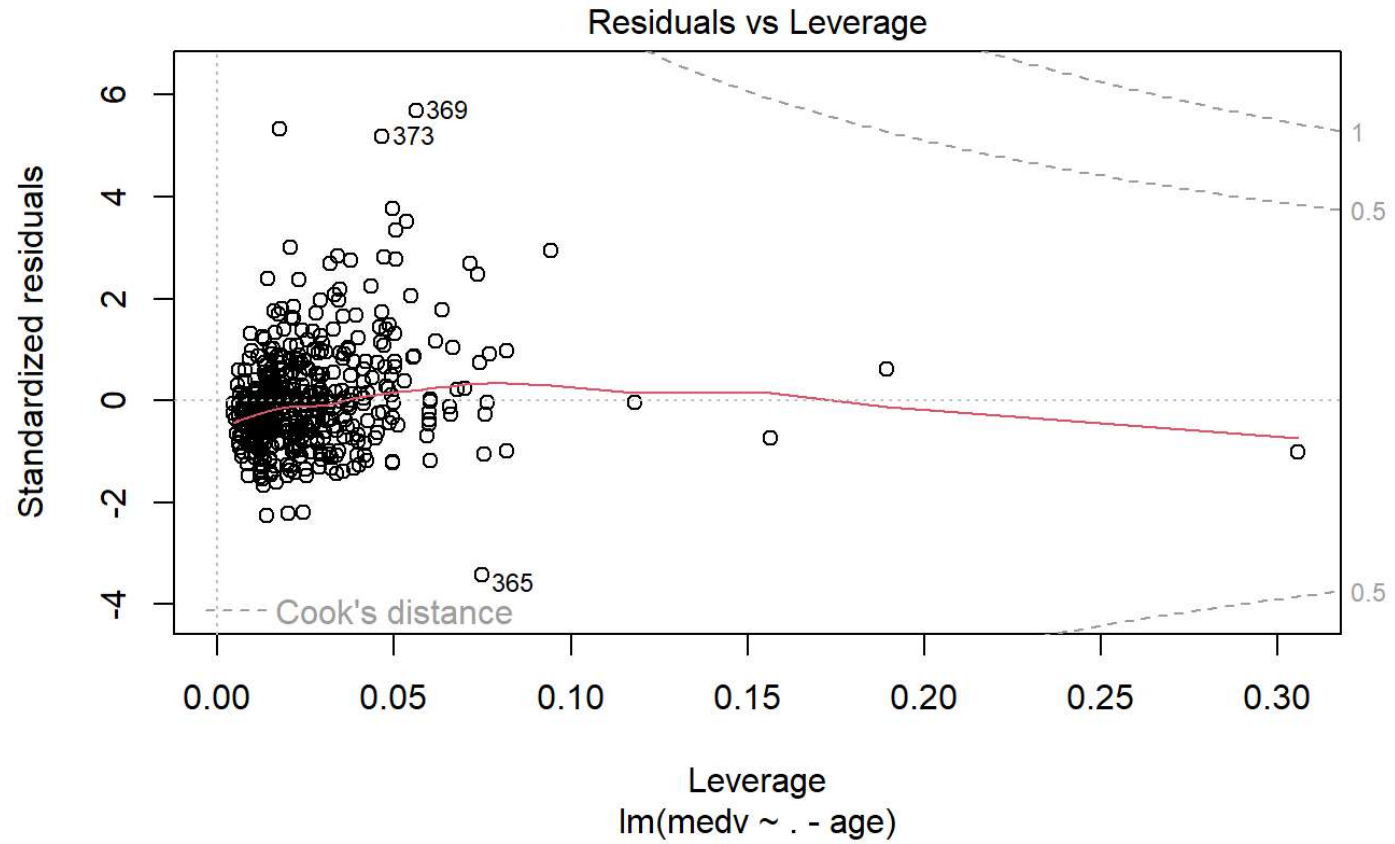
```
plot(lm.fit1)
```


Residuals vs Fitted
Residuals
Fitted values
lm(medv ~ . - age)
369
372
373


Normal Q-Q
Standardized residuals
Theoretical Quantiles
lm(medv ~ . - age)
369
372
373




# Interaction Terms

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```
summary(lm(medv~lstat*age,data=Boston))
```

```

Call:
lm(formula = medv ~ lstat * age, data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max 
-15.806  -4.045  -1.333   2.085  27.552 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)    
(Intercept) 36.0885359  1.4698355  24.553  < 2e-16 ***
lstat       -1.3921168  0.1674555  -8.313 8.78e-16 ***
age         -0.0007209  0.0198792  -0.036   0.9711    
lstat:age    0.0041560  0.0018518   2.244   0.0252 *  
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.149 on 502 degrees of freedom
Multiple R-squared:  0.5557,    Adjusted R-squared:  0.5531 
F-statistic: 209.3 on 3 and 502 DF,  p-value: < 2.2e-16
```

# Non-linear Transformations of the Predictors

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```
#lm() fn can also accomodate non linear transformations
lm.fit2=lm(medv~lstat+I(lstat^2))
summary(lm.fit2)
```

```
Call:
lm(formula = medv ~ lstat + I(lstat^2))

Residuals:
     Min       1Q   Median       3Q      Max
-15.2834  -3.8313  -0.5295   2.3095  25.4148

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept) 42.862007   0.872084   49.15   <2e-16 ***
lstat       -2.332821   0.123803  -18.84   <2e-16 ***
I(lstat^2)   0.043547   0.003745   11.63   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.524 on 503 degrees of freedom
Multiple R-squared:  0.6407,    Adjusted R-squared:  0.6393
F-statistic: 448.5 on 2 and 503 DF,  p-value: < 2.2e-16
```

**The near-zero p value suggests that the model performs better.**

We will now run anova() to see which quadratic fit is superior

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```
lm.fit=lm(medv~lstat)
anova(lm.fit,lm.fit2)
```

```
Analysis of Variance Table

Model 1: medv ~ lstat
Model 2: medv ~ lstat + I(lstat^2)
  Res.Df   RSS Df Sum of Sq     F    Pr(>F)
1    504 19472
2    503 15347  1    4125.1 135.2 < 2.2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

*From here we see that fit2 is much superior.*

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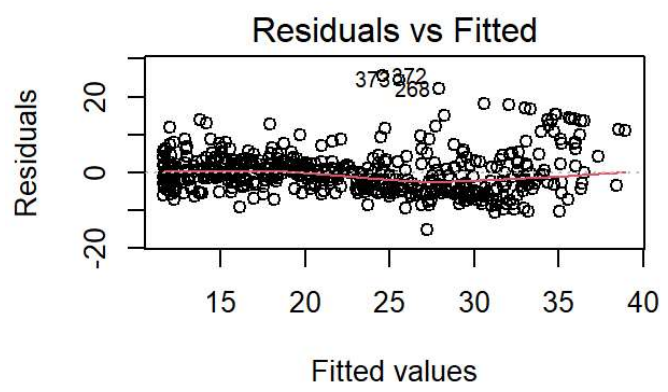
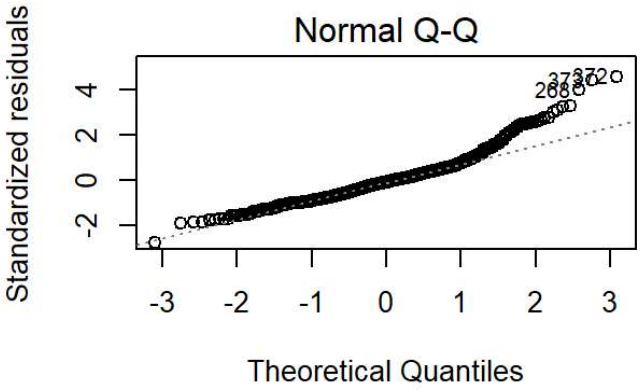
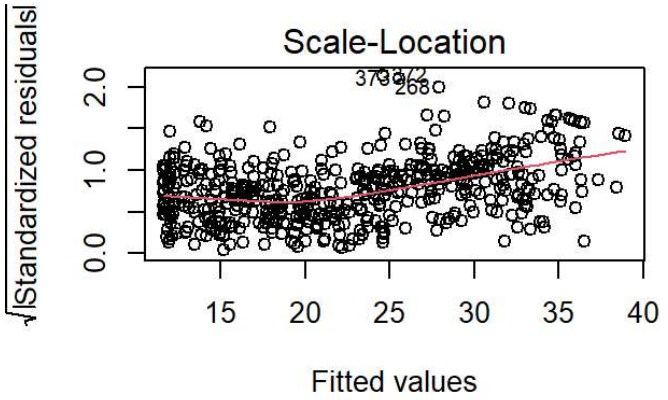
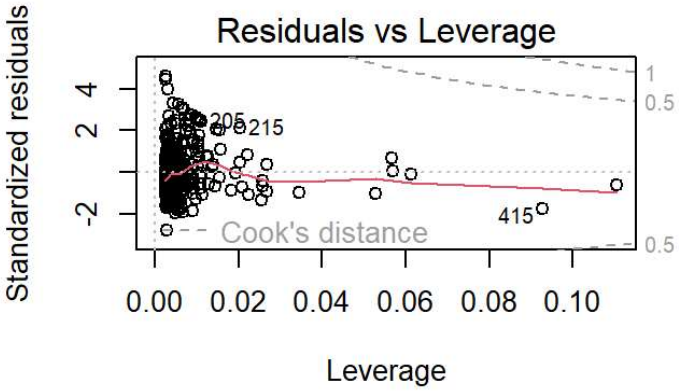
```
#plotting
par(mfrow=c(2,2))
plot(lm.fit2)
```

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```
lm.fit5=lm(medv~poly(lstat,5)) #creating polynomial inside lm
summary(lm.fit5)
```

```
Call:
lm(formula = medv ~ poly(lstat, 5))

Residuals:
     Min       1Q   Median       3Q      Max
-13.5433  -3.1039  -0.7052   2.0844  27.1153

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)       22.5328     0.2318  97.197  < 2e-16 ***
poly(lstat, 5)1 -152.4595     5.2148 -29.236  < 2e-16 ***
poly(lstat, 5)2   64.2272     5.2148  12.316  < 2e-16 ***
poly(lstat, 5)3  -27.0511     5.2148  -5.187 3.10e-07 ***
poly(lstat, 5)4   25.4517     5.2148   4.881 1.42e-06 ***
poly(lstat, 5)5  -19.2524     5.2148  -3.692 0.000247 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 5.215 on 500 degrees of freedom
Multiple R-squared:  0.6817,    Adjusted R-squared:  0.6785
F-statistic: 214.2 on 5 and 500 DF,  p-value: < 2.2e-16
```

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```
summary(lm(medv~log(rm),data=Boston)) #summary
```

```
Call:
lm(formula = medv ~ log(rm), data = Boston)

Residuals:
    Min      1Q  Median      3Q     Max
-19.487  -2.875  -0.104   2.837  39.816

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -76.488      5.028  -15.21   <2e-16 ***
log(rm)       54.055      2.739   19.73   <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 6.915 on 504 degrees of freedom
Multiple R-squared:  0.4358,    Adjusted R-squared:  0.4347
F-statistic: 389.3 on 1 and 504 DF,  p-value: < 2.2e-16
```

# Qualitative Predictors

Hide

```
#loading and previewing carseats data
fix(Carseats)
```

Hide

```
names(Carseats)
```

```
 [1] "Sales"       "CompPrice"   "Income"      "Advertising" "Population"  "Price"       "Shelve
Loc"   "Age"
 [9] "Education"   "Urban"       "US"
```

Hide

```
lm.fit=lm(Sales~.+Income:Advertising+Price:Age,data=Carseats)
summary(lm.fit)
```

```

Call:
lm(formula = Sales ~ . + Income:Advertising + Price:Age, data = Carseats)

Residuals:
    Min      1Q  Median      3Q     Max
-2.9208 -0.7503  0.0177  0.6754  3.3413

Coefficients:
                     Estimate Std. Error t value Pr(>|t|)
(Intercept)         6.5755654  1.0087470   6.519 2.22e-10 ***
CompPrice           0.0929371  0.0041183  22.567  < 2e-16 ***
Income              0.0108940  0.0026044   4.183 3.57e-05 ***
Advertising         0.0702462  0.0226091   3.107 0.002030 **
Population          0.0001592  0.0003679   0.433 0.665330
Price              -0.1008064  0.0074399 -13.549  < 2e-16 ***
ShelveLocGood       4.8486762  0.1528378  31.724  < 2e-16 ***
ShelveLocMedium     1.9532620  0.1257682  15.531  < 2e-16 ***
Age                -0.0579466  0.0159506  -3.633 0.000318 ***
Education          -0.0208525  0.0196131  -1.063 0.288361
UrbanYes            0.1401597  0.1124019   1.247 0.213171
USYes              -0.1575571  0.1489234  -1.058 0.290729
Income:Advertising  0.0007510  0.0002784   2.698 0.007290 **
Price:Age           0.0001068  0.0001333   0.801 0.423812
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 1.011 on 386 degrees of freedom
Multiple R-squared:  0.8761,    Adjusted R-squared:  0.8719
F-statistic:   210 on 13 and 386 DF,  p-value: < 2.2e-16
```

Hide

```
?Contrasts
```

## Description

These are substitutes for similarly named functions in the **stats** package (note the uppercase letter starting the second word in each function name). The only difference is that the contrast functions from the **car** package produce easier-to-read names for the contrasts when they are used in statistical models.

The functions and this documentation are adapted from the **stats** package.

Hide

```
attach(Carseats)
```

```
The following objects are masked from Carseats (pos = 3):

    Advertising, Age, CompPrice, Education, Income, Population, Price,
    Sales, ShelveLoc, Urban, US
```

Hide

```
contrasts(ShelveLoc) #retur the coding that r uses for dummy variables
```

```
       Good Medium
Bad       0      0
Good      1      0
Medium    0      1
```

# Writing Functions

**Now we will learn how to create functions**

Hide

```
#first assigning the fn name
LoadLibraries=function(){
 library(ISLR)
 library(MASS)
 print("The libraries have been loaded.")
 }
```

Hide

```
#now just put the name and see the fn
LoadLibraries
```

```
function(){
 library(ISLR)
 library(MASS)
 print("The libraries have been loaded.")
 }
```

Hide

```
LoadLibraries()
```

```
[1] "The libraries have been loaded."
```

***Chapter 3 ends.***