Regression Analysis lab 4

1 Model Adequacy Checking

1.1 Import data

```
delivery<-read.csv(file="D:/chilo/Regression 4/delivery.csv", header=T)
delivery
```

```
   observation  time cases distance
1            1 16.68     7      560
2            2 11.50     3      220
3            3 12.03     3      340
4            4 14.88     4       80
5            5 13.75     6      150
6            6 18.11     7      330
7            7  8.00     2      110
8            8 17.83     7      210
9            9 79.24    30     1460
10          10 21.50     5      605
11          11 40.33    16      688
12          12 21.00    10      215
13          13 13.50     4      255
14          14 19.75     6      462
15          15 24.00     9      448
16          16 29.00    10      776
17          17 15.35     6      200
18          18 19.00     7      132
19          19  9.50     3       36
20          20 35.10    17      770
21          21 17.90    10      140
22          22 52.32    26      810
23          23 18.75     9      450
24          24 19.83     8      635
25          25 10.75     4      150
```

1.2 Fit a multiple linear regression

```
attach(delivery)
dfit <- lm(time ~ cases + distance, data=delivery)
summary(dfit)
```

```
Call:
lm(formula = time ~ cases + distance, data = delivery)

Residuals:
   Min     1Q Median     3Q    Max
-5.788 -0.663  0.436  1.157  7.420

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  2.34123    1.09673    2.13  0.04417 *
cases        1.61591    0.17073    9.46  3.3e-09 ***
distance     0.01438    0.00361    3.98  0.00063 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 3.26 on 22 degrees of freedom
Multiple R-squared:  0.96,Adjusted R-squared:  0.956
F-statistic:  261 on 2 and 22 DF,  p-value: 4.69e-16

names(dfit)

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

dfit$fit

     1      2      3      4      5      6      7      8      9     10
21.708 10.354 12.080  9.956 14.194 18.400  7.155 16.673 71.820 19.124
    11     12     13     14     15     16     17     18     19     20
38.093 21.593 12.473 18.682 23.329 29.663 14.914 15.551  7.707 40.888
    21     22     23     24     25
20.514 56.007 23.358 24.403 10.963

dfit$res  # residuals

       1        2        3        4        5        6        7        8
-5.02808  1.14639 -0.04979  4.92435 -0.44440 -0.28957  0.84462  1.15660
       9       10       11       12       13       14       15       16
 7.41971  2.37641  2.23749 -0.59304  1.02701  1.06754  0.67120 -0.66293
      17       18       19       20       21       22       23       24
 0.43636  3.44862  1.79319 -5.78797 -2.61418 -3.68653 -4.60757 -4.57285
      25
-0.21258

names(summary(dfit))
```

```
 [1] "call"          "terms"         "residuals"     "coefficients"
 [5] "aliased"       "sigma"         "df"            "r.squared"
 [9] "adj.r.squared" "fstatistic"    "cov.unscaled"

sigmahat<-summary(dfit)$sigma
sigmahat

[1] 3.259

sigmahat2<-sigmahat^2
sigmahat2

[1] 10.62
```

1.3 Compute residuals

```
e<-dfit$res
e

##        1        2        3        4        5        6        7        8
## -5.02808  1.14639 -0.04979  4.92435 -0.44440 -0.28957  0.84462  1.15660
##        9       10       11       12       13       14       15       16
##  7.41971  2.37641  2.23749 -0.59304  1.02701  1.06754  0.67120 -0.66293
##       17       18       19       20       21       22       23       24
##  0.43636  3.44862  1.79319 -5.78797 -2.61418 -3.68653 -4.60757 -4.57285
##       25
## -0.21258
```

1.4 Compute standardized residuals

```
MSE<-sigmahat2
d<-e/sqrt(MSE)
d

##        1        2        3        4        5        6        7        8
## -1.54261  0.35171 -0.01528  1.51078 -0.13634 -0.08884  0.25913  0.35484
##        9       10       11       12       13       14       15       16
##  2.27635  0.72908  0.68646 -0.18194  0.31508  0.32752  0.20592 -0.20339
##       17       18       19       20       21       22       23       24
##  0.13387  1.05803  0.55015 -1.77574 -0.80202 -1.13102 -1.41359 -1.40294
##       25
## -0.06522
```

1.5 Compute hat matrix

```
n<-length(delivery$time)
n
```

```
[1] 25
```

```
delivery[,-c(1,2)]
```

```
   cases distance
1      7      560
2      3      220
3      3      340
4      4       80
5      6      150
6      7      330
7      2      110
8      7      210
9     30     1460
10     5      605
11    16      688
12    10      215
13     4      255
14     6      462
15     9      448
16    10      776
17     6      200
18     7      132
19     3       36
20    17      770
21    10      140
22    26      810
23     9      450
24     8      635
25     4      150
```

```
X<-cbind(1,delivery[,-c(1,2)])
X
```

```
   1 cases distance
1  1     7      560
2  1     3      220
3  1     3      340
4  1     4       80
5  1     6      150
6  1     7      330
```

```
7  1     2      110
8  1     7      210
9  1    30     1460
10 1     5      605
11 1    16      688
12 1    10      215
13 1     4      255
14 1     6      462
15 1     9      448
16 1    10      776
17 1     6      200
18 1     7      132
19 1     3       36
20 1    17      770
21 1    10      140
22 1    26      810
23 1     9      450
24 1     8      635
25 1     4      150
```

```
X <- as.matrix(X)
t(X) %*% X
```

```
             1  cases distance
1           25    219    10232
cases      219   3055   133899
distance 10232 133899  6725688
```

```
XtXi <- solve(t(X) %*% X)
XtXi
```

```
                  1      cases   distance
1         1.132e-01 -4.449e-03 -8.367e-05
cases    -4.449e-03  2.744e-03 -4.786e-05
distance -8.367e-05 -4.786e-05  1.229e-06
```

```
H<-X %*% XtXi %*% t(X)
H
```

```
           [,1]       [,2]      [,3]      [,4]      [,5]     [,6]
 [1,]  0.101802  5.837e-02  0.090697  0.008604  0.003380 0.039834
 [2,]  0.058366  7.070e-02  0.075871  0.057925  0.047449 0.048457
 [3,]  0.090697  7.587e-02  0.098735  0.036708  0.025068 0.046875
 [4,]  0.008604  5.792e-02  0.036708  0.085375  0.078395 0.049268
 [5,]  0.003380  4.745e-02  0.025068  0.078395  0.075010 0.046275
 [6,]  0.039834  4.846e-02  0.046875  0.049268  0.046275 0.042867
 [7,]  0.040771  7.271e-02  0.067402  0.074675  0.063128 0.050943
```

```
 [8,]  0.007503  4.329e-02  0.024011  0.070485  0.068656 0.044449
 [9,]  0.067316 -5.802e-02 -0.025066 -0.088464 -0.053256 0.004162
[10,]  0.138010  7.380e-02  0.124248 -0.004748 -0.014684 0.041311
[11,]  0.027909  3.168e-03  0.002687  0.010255  0.023027 0.028832
[12,] -0.027276  2.327e-02 -0.012502  0.077694  0.082230 0.041279
[13,]  0.055753  6.546e-02  0.070051  0.054435  0.045757 0.046961
[14,]  0.087440  6.089e-02  0.084513  0.023233  0.016821 0.042161
[15,]  0.047542  4.005e-02  0.044380  0.033802  0.033939 0.039241
[16,]  0.123871  4.743e-02  0.094385 -0.021491 -0.022398 0.033881
[17,]  0.016851  4.960e-02  0.034595  0.069555  0.065685 0.045616
[18,] -0.013512  3.993e-02  0.009150  0.084275  0.083203 0.045478
[19,]  0.008791  6.277e-02  0.040814  0.090456  0.081765 0.050884
[20,]  0.037960 -4.559e-05  0.005821 -0.001544  0.012569 0.026715
[21,] -0.047483  2.003e-02 -0.026792  0.090955  0.096218 0.042268
[22,] -0.059641 -5.903e-02 -0.098955  0.015665  0.048629 0.016873
[23,]  0.048081  4.014e-02  0.044761  0.033448  0.033566 0.039215
[24,]  0.109967  5.485e-02  0.092498 -0.001958 -0.005773 0.037810
[25,]  0.027464  6.094e-02  0.050046  0.072999  0.065339 0.048345
          [,7]       [,8]      [,9]     [,10]     [,11]     [,12]
 [1,]  0.040771  0.0075031  0.067316  0.138010  0.027909 -0.027276
 [2,]  0.072709  0.0432876 -0.058016  0.073796  0.003168  0.023266
 [3,]  0.067402  0.0240113 -0.025066  0.124248  0.002687 -0.012502
 [4,]  0.074675  0.0704845 -0.088464 -0.004748  0.010255  0.077694
 [5,]  0.063128  0.0686558 -0.053256 -0.014684  0.023027  0.082230
 [6,]  0.050943  0.0444493  0.004162  0.041311  0.028832  0.041279
 [7,]  0.081799  0.0562497 -0.096213  0.047231 -0.002918  0.043353
 [8,]  0.056250  0.0637256 -0.028787 -0.009141  0.029313  0.077046
 [9,] -0.096213 -0.0287874  0.498292  0.063685  0.174405 -0.003434
[10,]  0.047231 -0.0091413  0.063685  0.196296  0.014676 -0.066089
[11,] -0.002918  0.0293128  0.174405  0.014676  0.086133  0.048872
[12,]  0.043353  0.0770461 -0.003434 -0.066089  0.048872  0.113656
[13,]  0.066935  0.0423733 -0.040412  0.068828  0.009554  0.025533
[14,]  0.049330  0.0185375  0.032414  0.116491  0.021776 -0.010766
[15,]  0.037274  0.0349101  0.052550  0.051555  0.041411  0.031507
[16,]  0.018542 -0.0130706  0.150607  0.169774  0.046622 -0.053558
[17,]  0.060917  0.0606240 -0.039527  0.006338  0.022827  0.067327
[18,]  0.059699  0.0762552 -0.050205 -0.041935  0.029626  0.100295
[19,]  0.080846  0.0728446 -0.108539 -0.003564  0.003905  0.078109
[20,] -0.010769  0.0208486  0.204914  0.029469  0.092330  0.037130
[21,]  0.046669  0.0890938 -0.024027 -0.097621  0.049172  0.136010
[22,] -0.050566  0.0567943  0.287840 -0.130863  0.150906  0.139507
[23,]  0.037185  0.0345888  0.053099  0.052396  0.041403  0.030911
[24,]  0.033229  0.0001633  0.095904  0.149859  0.034135 -0.036931
[25,]  0.071579  0.0592400 -0.069243  0.024682  0.009975  0.056830
          [,13]     [,14]   [,15]     [,16]     [,17]     [,18]     [,19]
```

```
 [1,]  0.055753  0.087440 0.04754  0.123871  0.016851 -0.013512  0.008791
 [2,]  0.065464  0.060890 0.04005  0.047434  0.049603  0.039927  0.062775
 [3,]  0.070051  0.084513 0.04438  0.094385  0.034595  0.009150  0.040814
 [4,]  0.054435  0.023233 0.03380 -0.021491  0.069555  0.084275  0.090456
 [5,]  0.045757  0.016821 0.03394 -0.022398  0.065685  0.083203  0.081765
 [6,]  0.046961  0.042161 0.03924  0.033881  0.045616  0.045478  0.050884
 [7,]  0.066935  0.049330 0.03727  0.018542  0.060917  0.059699  0.080846
 [8,]  0.042373  0.018537 0.03491 -0.013071  0.060624  0.076255  0.072845
 [9,] -0.040412  0.032414 0.05255  0.150607 -0.039527 -0.050205 -0.108539
[10,]  0.068828  0.116491 0.05156  0.169774  0.006338 -0.041935 -0.003564
[11,]  0.009554  0.021776 0.04141  0.046622  0.022827  0.029626  0.003905
[12,]  0.025533 -0.010766 0.03151 -0.053558  0.067327  0.100295  0.078109
[13,]  0.061125  0.057684 0.04012  0.046980  0.047668  0.039391  0.058430
[14,]  0.057684  0.078243 0.04520  0.099675  0.026665  0.003182  0.024666
[15,]  0.040118  0.045200 0.04111  0.051754  0.035744  0.032095  0.033408
[16,]  0.046980  0.099675 0.05175  0.165940 -0.002835 -0.043589 -0.024559
[17,]  0.047668  0.026665 0.03574 -0.002835  0.059432  0.070379  0.072615
[18,]  0.039391  0.003182 0.03209 -0.043589  0.070379  0.096260  0.087119
[19,]  0.058430  0.024666 0.03341 -0.024559  0.072615  0.087119  0.096449
[20,]  0.007011  0.027823 0.04318  0.064558  0.015014  0.017035 -0.009041
[21,]  0.022666 -0.025531 0.02880 -0.082903  0.076707  0.119531  0.091835
[22,] -0.042553 -0.055165 0.03387 -0.047122  0.031995  0.082743  0.002177
[23,]  0.040194  0.045593 0.04118  0.052537  0.035494  0.031582  0.033042
[24,]  0.052944  0.092109 0.04905  0.139068  0.009914 -0.024307 -0.002874
[25,]  0.057111  0.037013 0.03633  0.005897  0.060800  0.066322  0.077645
          [,20]     [,21]     [,22]   [,23]      [,24]     [,25]
 [1,]  3.796e-02 -0.04748 -0.059641 0.04808  0.1099666  0.027464
 [2,] -4.559e-05  0.02003 -0.059035 0.04014  0.0548508  0.060940
 [3,]  5.821e-03 -0.02679 -0.098955 0.04476  0.0924977  0.050046
 [4,] -1.544e-03  0.09095  0.015665 0.03345 -0.0019581  0.072999
 [5,]  1.257e-02  0.09622  0.048629 0.03357 -0.0057726  0.065339
 [6,]  2.672e-02  0.04227  0.016873 0.03921  0.0378101  0.048345
 [7,] -1.077e-02  0.04667 -0.050566 0.03719  0.0332288  0.071579
 [8,]  2.085e-02  0.08909  0.056794 0.03459  0.0001633  0.059240
 [9,]  2.049e-01 -0.02403  0.287840 0.05310  0.0959036 -0.069243
[10,]  2.947e-02 -0.09762 -0.130863 0.05240  0.1498593  0.024682
[11,]  9.233e-02  0.04917  0.150906 0.04140  0.0341350  0.009975
[12,]  3.713e-02  0.13601  0.139507 0.03091 -0.0369308  0.056830
[13,]  7.011e-03  0.02267 -0.042553 0.04019  0.0529436  0.057111
[14,]  2.782e-02 -0.02553 -0.055165 0.04559  0.0921092  0.037013
[15,]  4.318e-02  0.02880  0.033869 0.04118  0.0490544  0.036328
[16,]  6.456e-02 -0.08290 -0.047122 0.05254  0.1390681  0.005897
[17,]  1.501e-02  0.07671  0.031995 0.03549  0.0099136  0.060800
[18,]  1.704e-02  0.11953  0.082743 0.03158 -0.0243072  0.066322
[19,] -9.041e-03  0.09183  0.002177 0.03304 -0.0028743  0.077645
```

```
[20,]  1.017e-01  0.03346  0.151752 0.04327  0.0469728  0.001878
[21,]  3.346e-02  0.16528  0.164458 0.02802 -0.0604601  0.063639
[22,]  1.518e-01  0.16446  0.391575 0.03320 -0.0564665 -0.007622
[23,]  4.327e-02  0.02802  0.033204 0.04126  0.0496818  0.036147
[24,]  4.697e-02 -0.06046 -0.056466 0.04968  0.1206083  0.020003
[25,]  1.878e-03  0.06364 -0.007622 0.03615  0.0200026  0.066643
```

1.6 Compute internally studentized residuals

```
h<-diag(H)
h

##  [1] 0.10180 0.07070 0.09873 0.08537 0.07501 0.04287 0.08180 0.06373
##  [9] 0.49829 0.19630 0.08613 0.11366 0.06112 0.07824 0.04111 0.16594
## [17] 0.05943 0.09626 0.09645 0.10168 0.16528 0.39158 0.04126 0.12061
## [25] 0.06664

r<-e/sqrt(MSE*(1-h))
r

##        1        2        3        4        5        6        7        8
## -1.62768  0.36484 -0.01609  1.57972 -0.14176 -0.09081  0.27042  0.36672
##        9       10       11       12       13       14       15       16
##  3.21376  0.81325  0.71808 -0.19326  0.32518  0.34114  0.21029 -0.22270
##       17       18       19       20       21       22       23       24
##  0.13804  1.11295  0.57877 -1.87355 -0.87784 -1.45000 -1.44369 -1.49606
##       25
## -0.06751
```

1.7 Compute externally studentized residuals

```
dMSE<-((n-3)*MSE-e^2/(1-h))/(n-3-1)
t<-e/sqrt(dMSE*(1-h))
t

       1        2        3        4        5        6        7        8
-1.69563  0.35754 -0.01572  1.63916 -0.13856 -0.08874  0.26465  0.35939
       9       10       11       12       13       14       15       16
 4.31078  0.80678  0.70994 -0.18897  0.31847  0.33418  0.20566 -0.21783
      17       18       19       20       21       22       23       24
 0.13492  1.11933  0.56981 -1.99668 -0.87309 -1.48962 -1.48247 -1.54222
      25
-0.06596
```

```
t1<-rstudent(dfit)
t1

       1        2        3        4        5        6        7        8
-1.69563  0.35754 -0.01572  1.63916 -0.13856 -0.08874  0.26465  0.35939
       9       10       11       12       13       14       15       16
 4.31078  0.80678  0.70994 -0.18897  0.31847  0.33418  0.20566 -0.21783
      17       18       19       20       21       22       23       24
 0.13492  1.11933  0.56981 -1.99668 -0.87309 -1.48962 -1.48247 -1.54222
      25
-0.06596
```

1.8 Hypothesis testing for outliers

```
qt(1-0.05/(2*25),n-3-1)

[1] 3.527

t[9]

    9
4.311
```

1.9 Compute PRESS and SSE

```
ei<-e/(1-h)
ei

       1        2        3        4        5        6        7        8
-5.59797  1.23360 -0.05525  5.38401 -0.48044 -0.30254  0.91987  1.23533
       9       10       11       12       13       14       15       16
14.78890  2.95683  2.44838 -0.66909  1.09387  1.15815  0.69998 -0.79482
      17       18       19       20       21       22       23       24
 0.46393  3.81595  1.98461 -6.44314 -3.13179 -6.05913 -4.80586 -5.20002
      25
-0.22776

ei^2

        1         2         3         4         5         6         7
3.134e+01 1.522e+00 3.052e-03 2.899e+01 2.308e-01 9.153e-02 8.462e-01
        8         9        10        11        12        13        14
1.526e+00 2.187e+02 8.743e+00 5.995e+00 4.477e-01 1.197e+00 1.341e+00
```

```
       15        16        17        18        19        20        21
4.900e-01 6.317e-01 2.152e-01 1.456e+01 3.939e+00 4.151e+01 9.808e+00
       22        23        24        25
3.671e+01 2.310e+01 2.704e+01 5.188e-02

PRESS<-sum(ei^2)
PRESS

[1] 459

SSE<-sum(e^2)
SSE

[1] 233.7
```

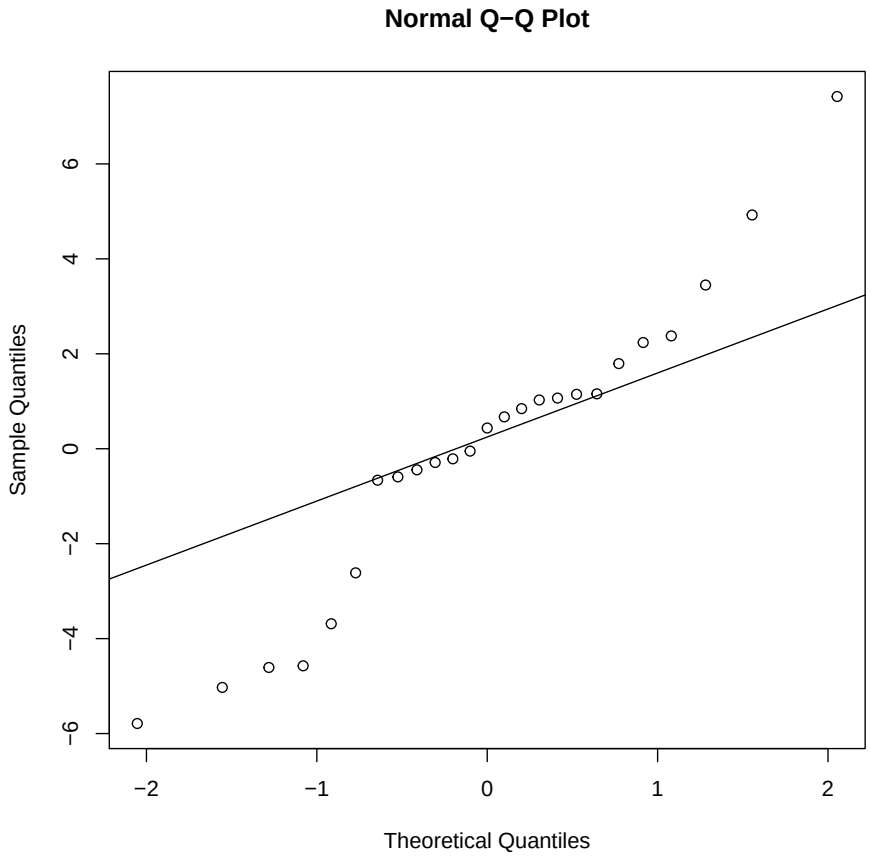
1.10 Table 4.1

```
cbind(e,d,r,h,ei,t,ei^2)

          e        d        r       h       ei        t
1  -5.02808 -1.54261 -1.62768 0.10180 -5.59797 -1.69563 3.134e+01
2   1.14639  0.35171  0.36484 0.07070  1.23360  0.35754 1.522e+00
3  -0.04979 -0.01528 -0.01609 0.09873 -0.05525 -0.01572 3.052e-03
4   4.92435  1.51078  1.57972 0.08537  5.38401  1.63916 2.899e+01
5  -0.44440 -0.13634 -0.14176 0.07501 -0.48044 -0.13856 2.308e-01
6  -0.28957 -0.08884 -0.09081 0.04287 -0.30254 -0.08874 9.153e-02
7   0.84462  0.25913  0.27042 0.08180  0.91987  0.26465 8.462e-01
8   1.15660  0.35484  0.36672 0.06373  1.23533  0.35939 1.526e+00
9   7.41971  2.27635  3.21376 0.49829 14.78890  4.31078 2.187e+02
10  2.37641  0.72908  0.81325 0.19630  2.95683  0.80678 8.743e+00
11  2.23749  0.68646  0.71808 0.08613  2.44838  0.70994 5.995e+00
12 -0.59304 -0.18194 -0.19326 0.11366 -0.66909 -0.18897 4.477e-01
13  1.02701  0.31508  0.32518 0.06112  1.09387  0.31847 1.197e+00
14  1.06754  0.32752  0.34114 0.07824  1.15815  0.33418 1.341e+00
15  0.67120  0.20592  0.21029 0.04111  0.69998  0.20566 4.900e-01
16 -0.66293 -0.20339 -0.22270 0.16594 -0.79482 -0.21783 6.317e-01
17  0.43636  0.13387  0.13804 0.05943  0.46393  0.13492 2.152e-01
18  3.44862  1.05803  1.11295 0.09626  3.81595  1.11933 1.456e+01
19  1.79319  0.55015  0.57877 0.09645  1.98461  0.56981 3.939e+00
20 -5.78797 -1.77574 -1.87355 0.10168 -6.44314 -1.99668 4.151e+01
21 -2.61418 -0.80202 -0.87784 0.16528 -3.13179 -0.87309 9.808e+00
22 -3.68653 -1.13102 -1.45000 0.39158 -6.05913 -1.48962 3.671e+01
23 -4.60757 -1.41359 -1.44369 0.04126 -4.80586 -1.48247 2.310e+01
24 -4.57285 -1.40294 -1.49606 0.12061 -5.20002 -1.54222 2.704e+01
25 -0.21258 -0.06522 -0.06751 0.06664 -0.22776 -0.06596 5.188e-02
```

2 Residual plots

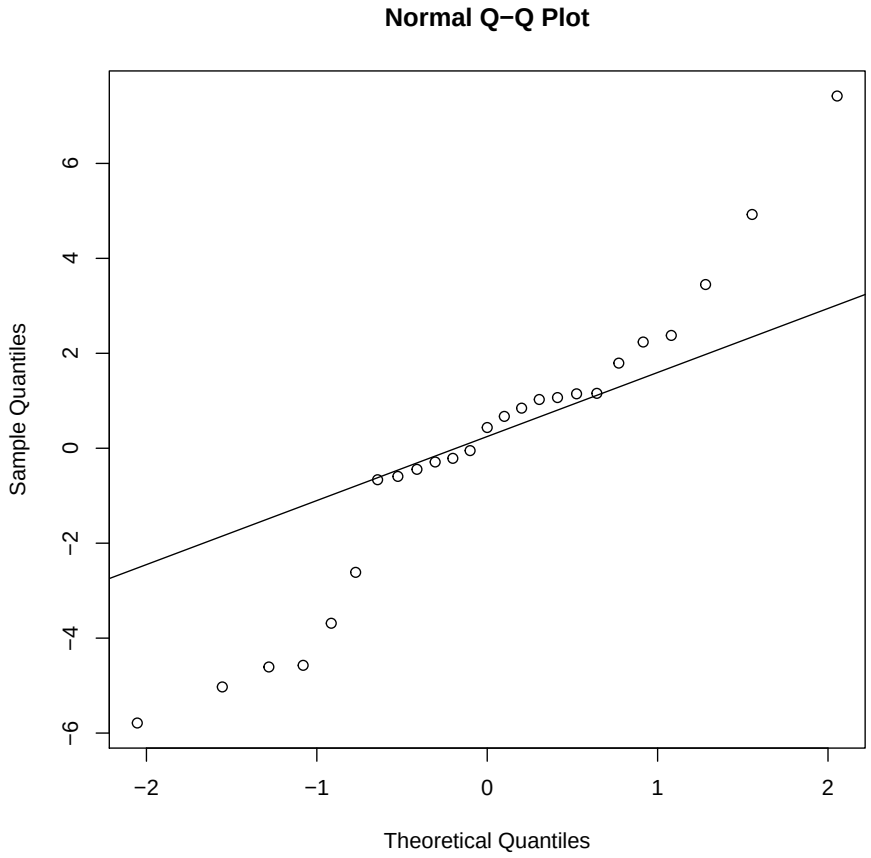
2.1 Normal Q-Q plot of residuals

```
dfit <- lm(time ~ cases + distance, data=delivery)
qqnorm(residuals(dfit))
qqline(residuals(dfit))
```



2.2 Normal Q-Q plot of residuals

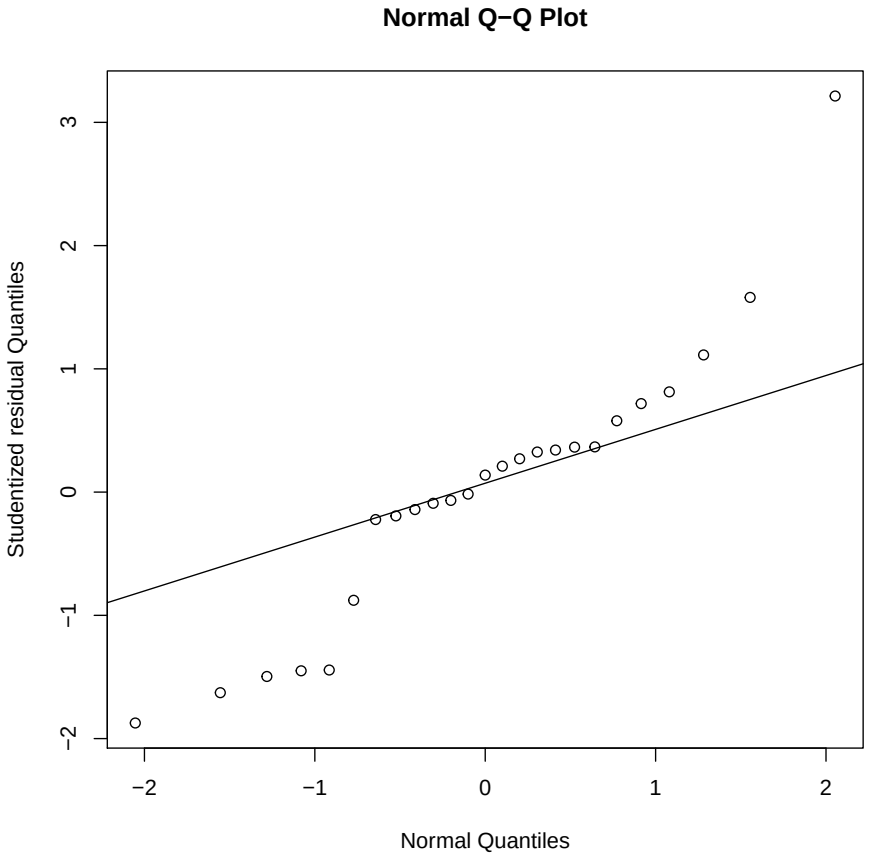
```
qqnorm(residuals(dfit))
qqline(residuals(dfit))
```




```
# residuals are from a heavy-tailed distribution
```

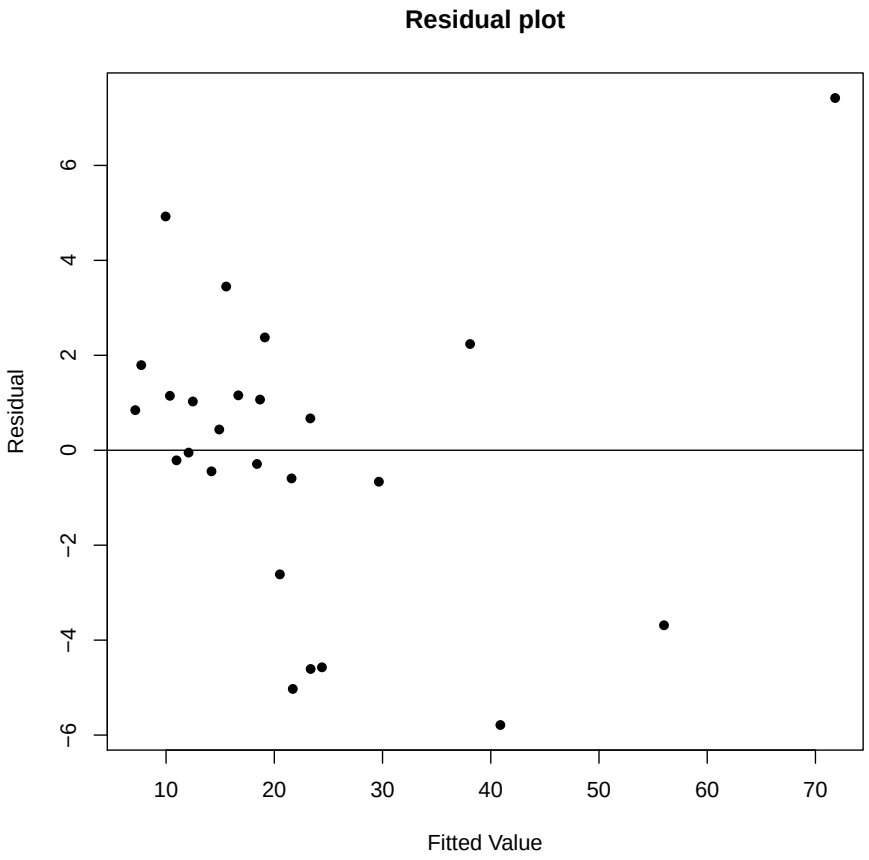
2.3 Normal Q-Q plot of studentized residuals

```
qqnorm(r, xlab="Normal Quantiles", ylab="Studentized residual Quantiles")
qqline(r)
```

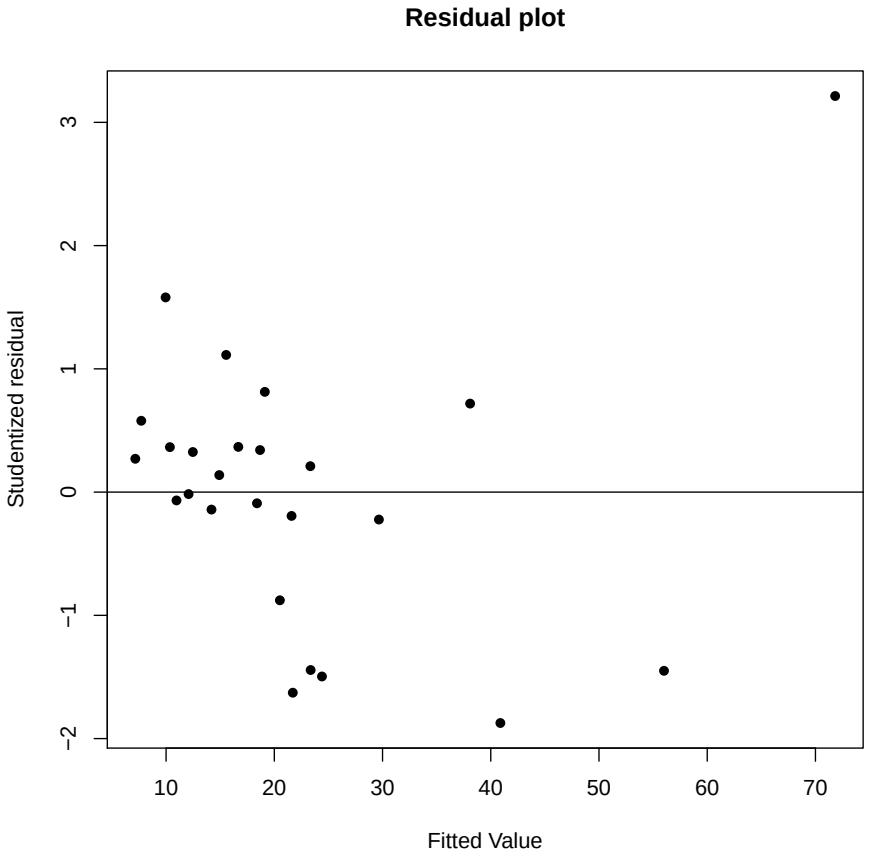


2.4 Residual plots

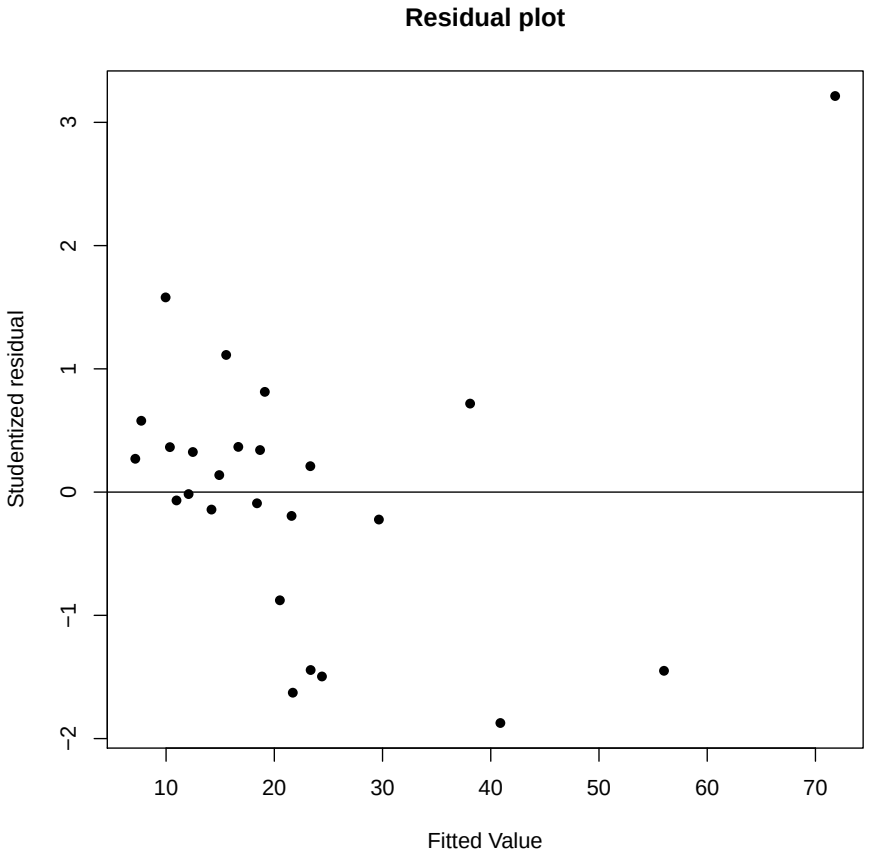
```
plot(dfit$fit,dfit$res,xlab="Fitted Value",ylab="Residual", pch=16)
title(main="Residual plot")
abline(h=0)
```



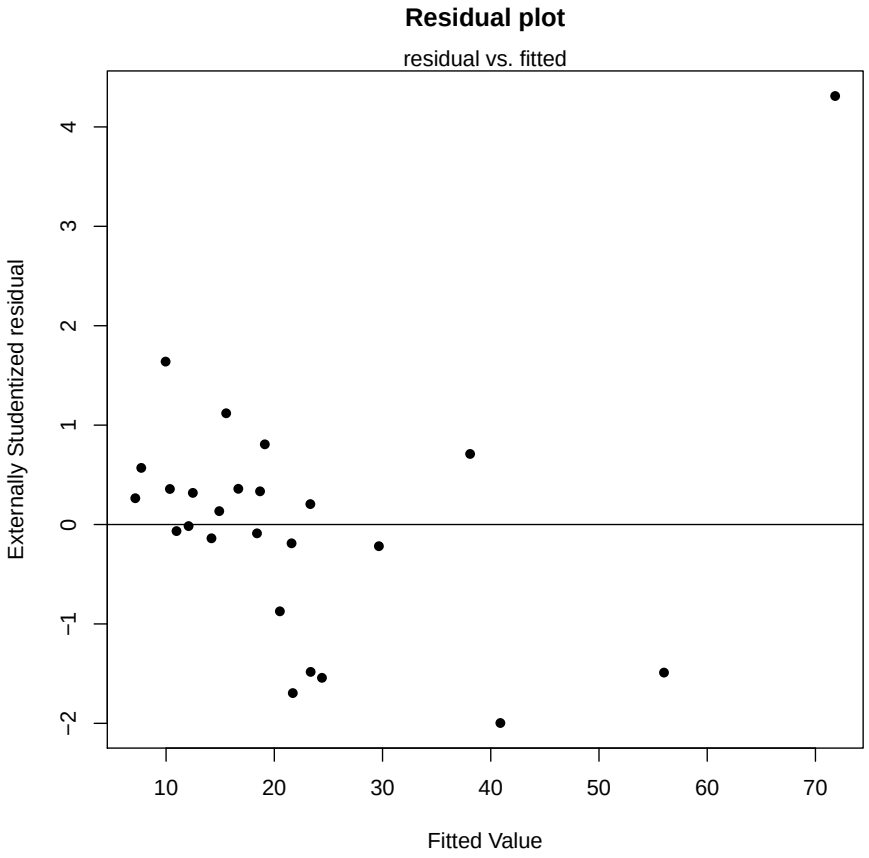

```
plot(dfit$fit,r,xlab="Fitted Value",ylab="Studentized residual", pch=16)
title(main="Residual plot")
abline(h=0)
```



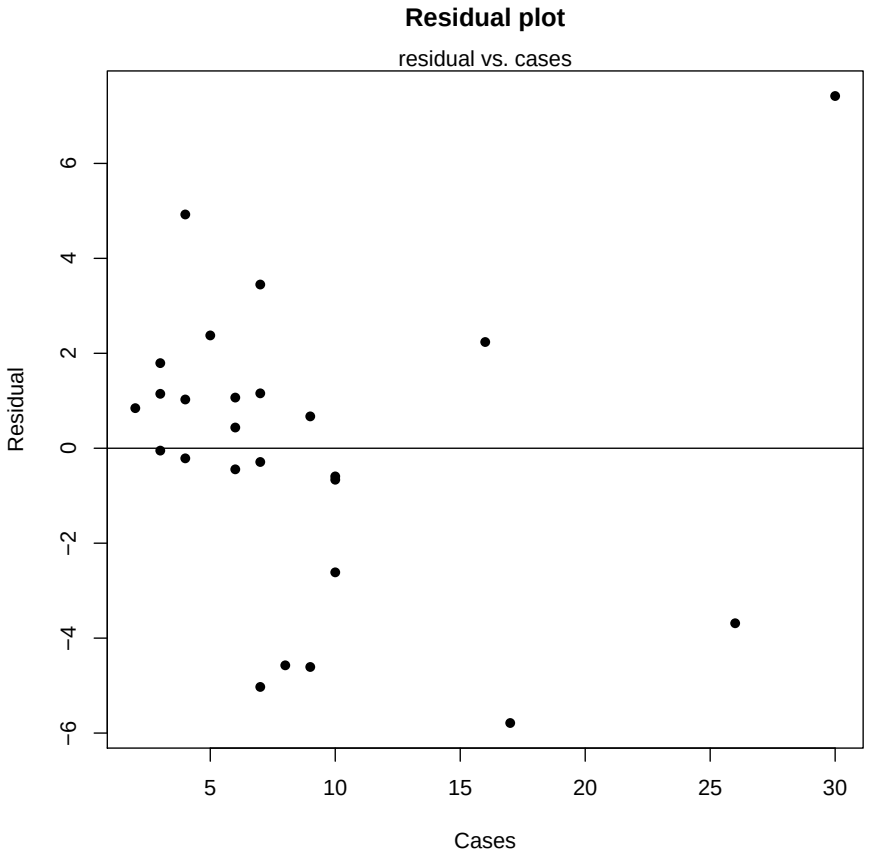

```
plot(dfit$fit,r,xlab="Fitted Value",ylab="Studentized residual", pch=16)
title(main="Residual plot")
abline(h=0)
identify(dfit$fit,r)
```



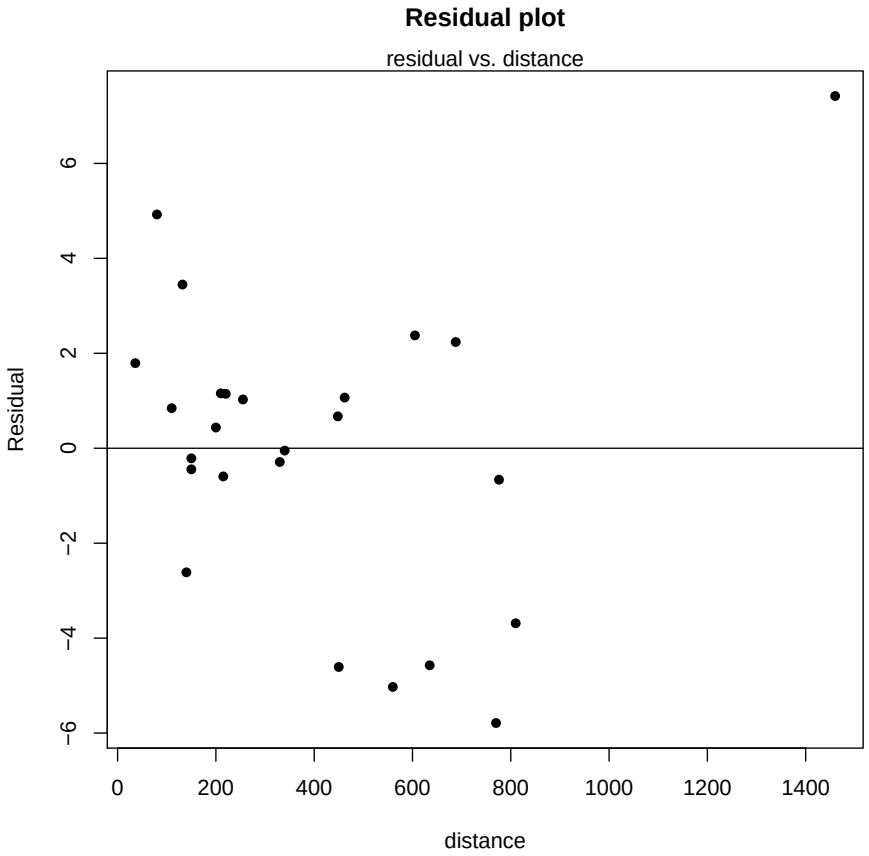

```
integer(0)

plot(dfit$fit,t,xlab="Fitted Value",
     ylab="Externally Studentized residual", pch=16)
title(main="Residual plot")
mtext(side=3, line=0, text="residual vs. fitted")
abline(h=0)
```




```
attach(delivery)

The following objects are masked from delivery (position 3):

    cases, distance, observation, time

plot(cases, dfit$res,xlab="Cases",ylab="Residual", pch=16)
title(main="Residual plot")
mtext(side=3, line=0, text="residual vs. cases")
abline(h=0)
```

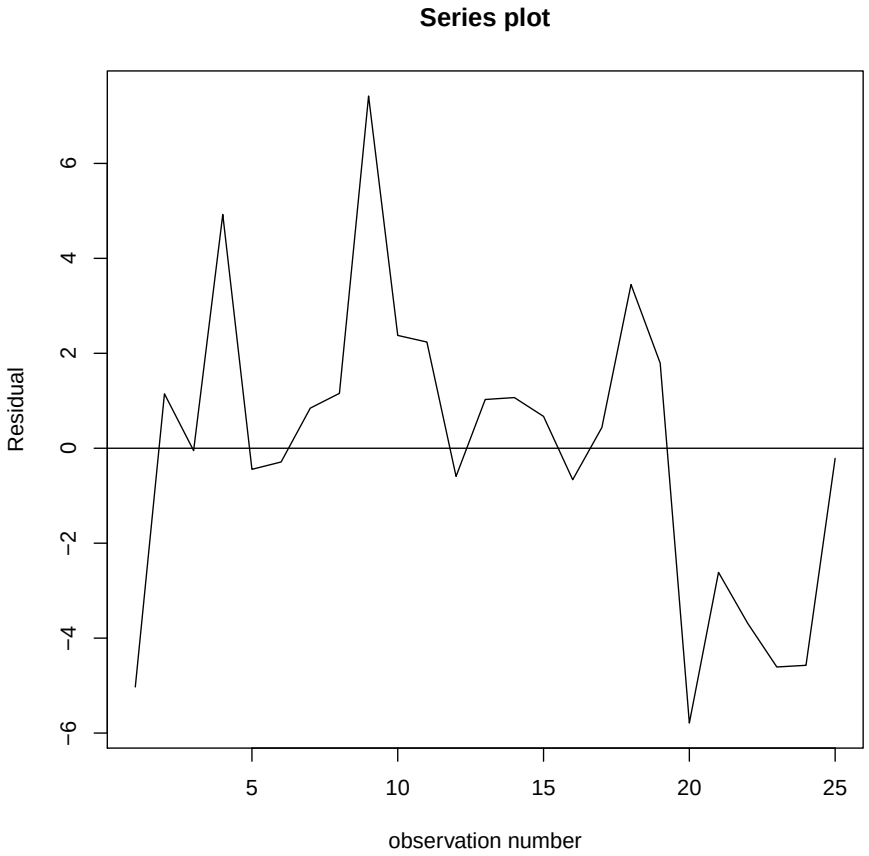



```
plot(distance, dfit$res,xlab="distance",ylab="Residual", pch=16)
title(main="Residual plot")
mtext(side=3, line=0, text="residual vs. distance")
abline(h=0)
```



2.5 Series plot

```
ts.plot(dfit$res,xlab="observation number",ylab="Residual")
title(main="Series plot")
abline(h=0)
```

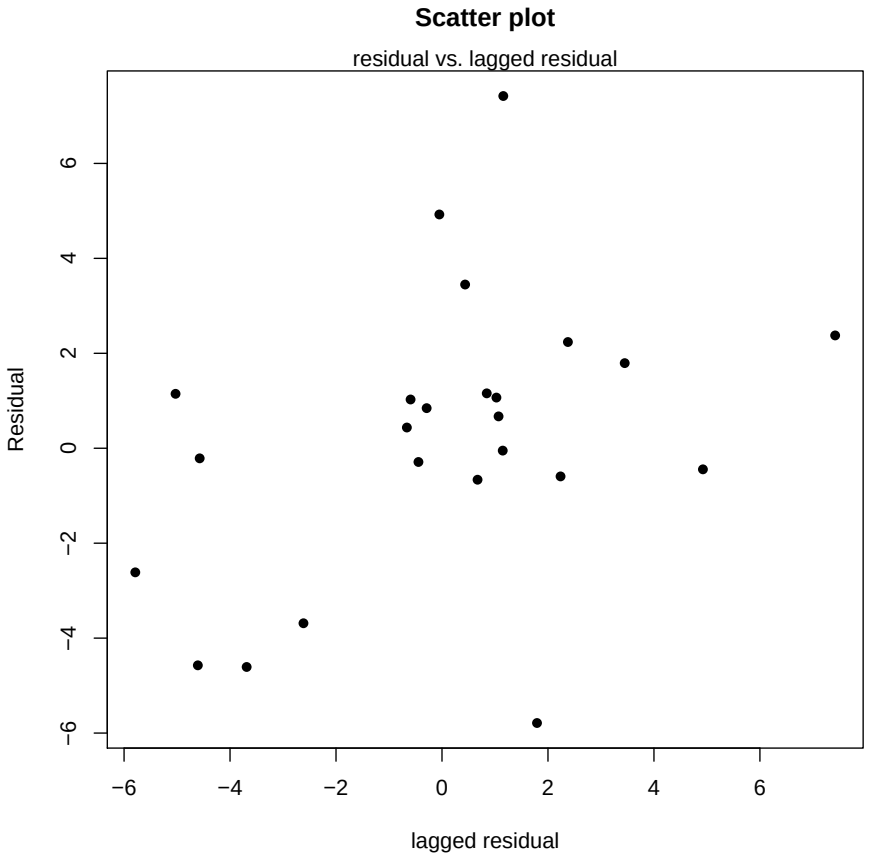


2.6 Scatter plot

```
lagres<-0
for(i in 1:24){lagres[i+1]=dfit$res[i]}
lagres[1]<-NA
lagres

 [1]       NA -5.02808  1.14639 -0.04979  4.92435 -0.44440 -0.28957
 [8]  0.84462  1.15660  7.41971  2.37641  2.23749 -0.59304  1.02701
[15]  1.06754  0.67120 -0.66293  0.43636  3.44862  1.79319 -5.78797
[22] -2.61418 -3.68653 -4.60757 -4.57285

cbind(dfit$res, lagres)

              lagres
1  -5.02808       NA
```

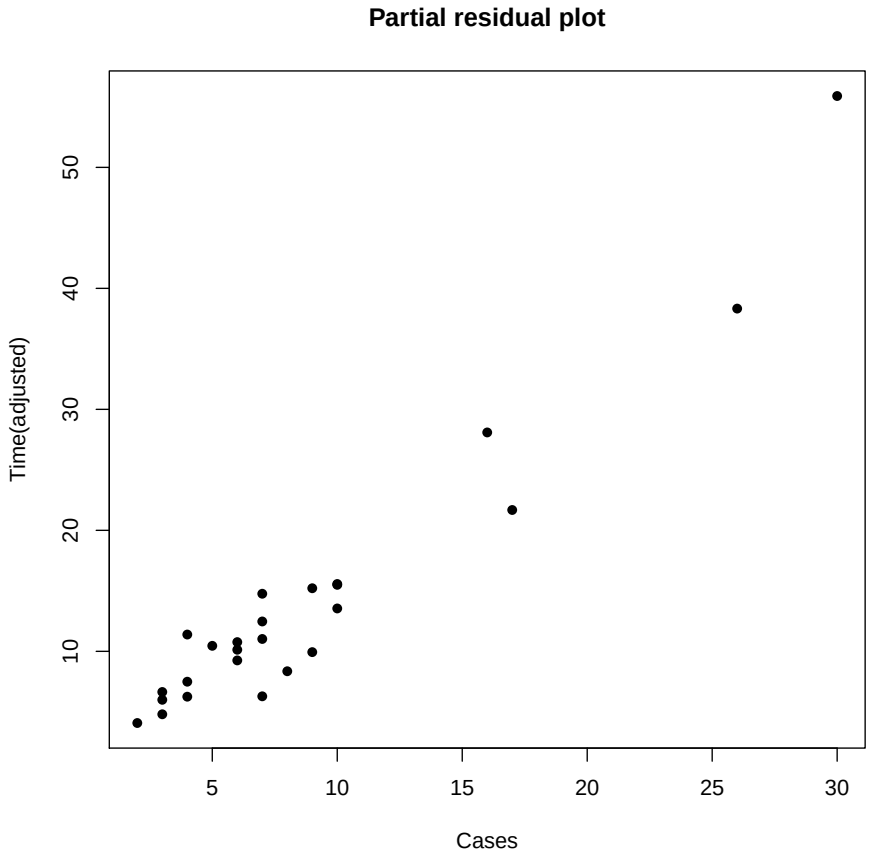
```
2   1.14639 -5.02808
3  -0.04979  1.14639
4   4.92435 -0.04979
5  -0.44440  4.92435
6  -0.28957 -0.44440
7   0.84462 -0.28957
8   1.15660  0.84462
9   7.41971  1.15660
10  2.37641  7.41971
11  2.23749  2.37641
12 -0.59304  2.23749
13  1.02701 -0.59304
14  1.06754  1.02701
15  0.67120  1.06754
16 -0.66293  0.67120
17  0.43636 -0.66293
18  3.44862  0.43636
19  1.79319  3.44862
20 -5.78797  1.79319
21 -2.61418 -5.78797
22 -3.68653 -2.61418
23 -4.60757 -3.68653
24 -4.57285 -4.60757
25 -0.21258 -4.57285
```

```
plot(lagres, dfit$res,xlab="lagged residual",ylab="Residual", pch=16)
title(main="Scatter plot")
mtext(side=3, line=0, text="residual vs. lagged residual")
```



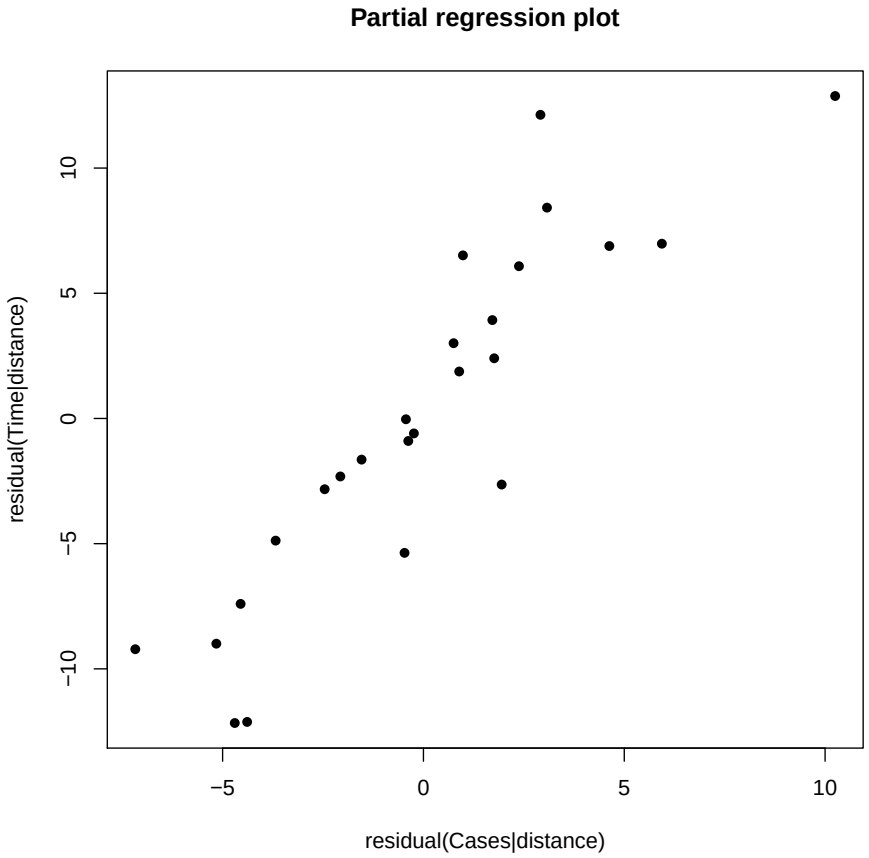
2.7 Partial residual plot

```
dfit <- lm(time ~ cases + distance, data=delivery)
dfit$coef

(Intercept)       cases    distance
    2.34123     1.61591     0.01438

pres<-dfit$res+dfit$coef['cases']*cases
plot(cases, pres, xlab="Cases",ylab="Time(adjusted)", pch=16)
title(main="Partial residual plot")
```

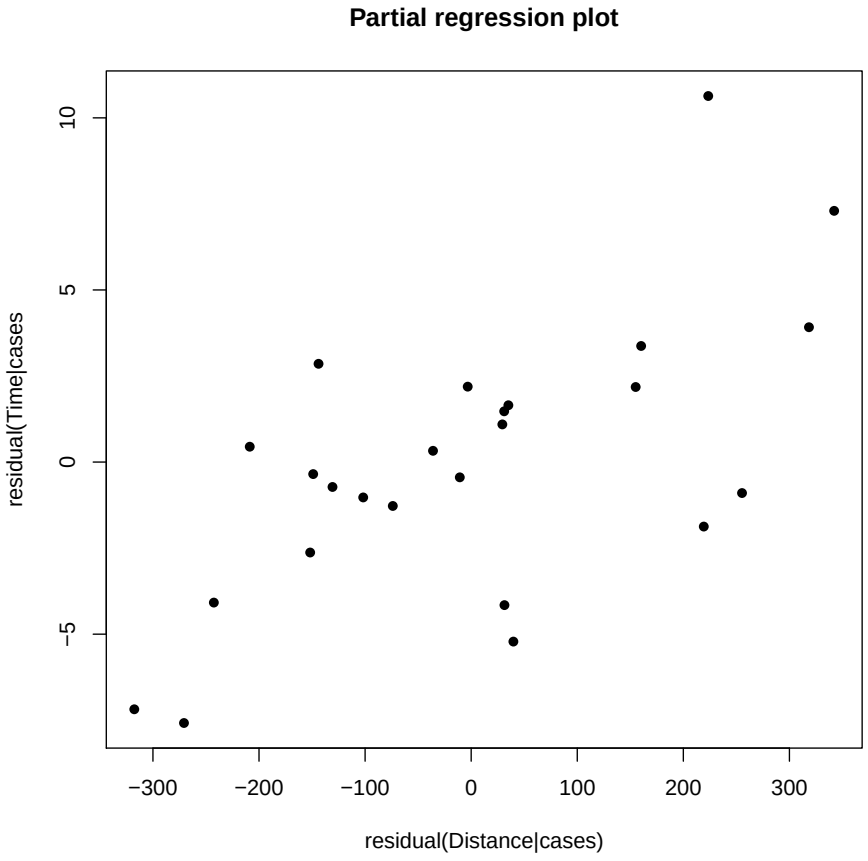


2.8 Partial regression plot

```
dfit1 <- lm(time ~ distance, data=delivery)$res
dfit2 <- lm(cases ~ distance, data=delivery)$res
plot(dfit2, dfit1, xlab="residual(Cases|distance)",
     ylab="residual(Time|distance)", pch=16)
title(main="Partial regression plot")
```



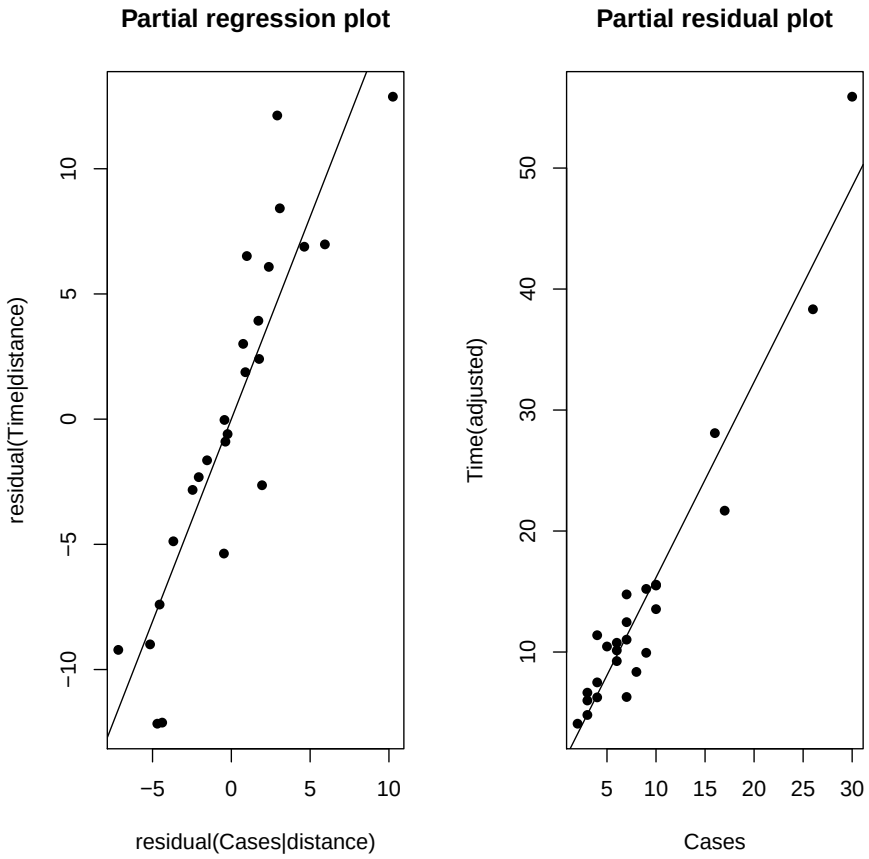

```
dfit3 <- lm(time ~ cases, data=delivery)$res
dfit4 <- lm(distance ~ cases, data=delivery)$res
plot(dfit4, dfit3, xlab="residual(Distance|cases)",
     ylab="residual(Time|cases", pch=16)
title(main="Partial regression plot")
```



2.9 Both Partial regression and Partial residual plots

```
dfit <- lm(time ~ cases + distance, data=delivery)
dfit$coef

(Intercept)       cases    distance
    2.34123     1.61591     0.01438

par(mfrow=c(1,2))
dfit1 <- lm(time ~ distance, data=delivery)$res
dfit2 <- lm(cases ~ distance, data=delivery)$res
plot(dfit2, dfit1, xlab="residual(Cases|distance)",
     ylab="residual(Time|distance)", pch=16)
title(main="Partial regression plot")
abline(0,dfit$coef[2])
```

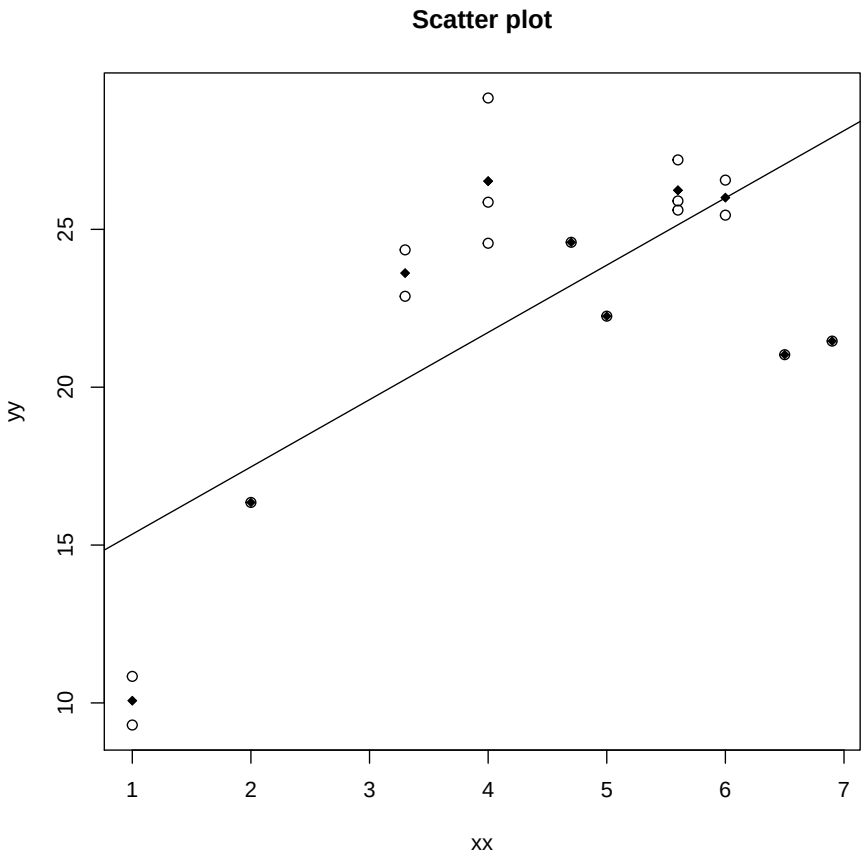
```
dfit <- lm(time ~ cases + distance, data=delivery)
dfit$coef

(Intercept)       cases    distance
    2.34123     1.61591     0.01438

pres<-dfit$res+dfit$coef[2]*cases
plot(cases, pres, xlab="Cases",ylab="Time(adjusted)", pch=16)
title(main="Partial residual plot")
abline(0,dfit$coef[2])
```




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

3 Lack of fit test

```r
xx<-c(1.0, 1.0, 2.0, 3.3, 3.3, 4.0, 4.0, 4.0, 4.7,
      5.0, 5.6, 5.6, 5.6, 6.0, 6.0, 6.5, 6.9)
yy<-c(10.84, 9.30, 16.35, 22.88, 24.35, 24.56, 25.86,
      29.16, 24.59, 22.25, 25.90, 27.20,
      25.61, 25.45, 26.56, 21.03, 21.46)
g<-lm(yy ~ xx)
summary(g)


Call:
lm(formula = yy ~ xx)

Residuals:
   Min     1Q Median     3Q    Max
-6.454 -1.616  0.564  2.636  7.425

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)   13.214      2.665    4.96  0.00017 ***
xx             2.130      0.565    3.77  0.00184 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 4.08 on 15 degrees of freedom
Multiple R-squared:  0.487,Adjusted R-squared:  0.453
F-statistic: 14.2 on 1 and 15 DF,  p-value: 0.00184

anova(g)

Analysis of Variance Table

Response: yy
          Df Sum Sq Mean Sq F value Pr(>F)
xx         1    238   237.5    14.2 0.0018 **
Residuals 15    250    16.7
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

plot(xx,yy, main="Scatter plot")
abline(g$coef)
ga <- lm(yy ~ factor(xx))
points(xx, ga$fit, pch=18)
```




```
anova(g,ga)

Analysis of Variance Table

Model 1: yy ~ xx
Model 2: yy ~ factor(xx)
  Res.Df   RSS Df Sum of Sq    F Pr(>F)
1     15 250.1
2      7  15.6  8       235 13.2 0.0014 **
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```