PROBLEM 15

Clerical staff work hours. In any production process in which one or more workers are engaged in a variety of tasks, the total time spent in production varies as a function of the size of the work pool and the level of output of the various activities.

For example, in a large metropolitan department store, the number of hours worked (Y) per day by the clerical staff may depend on the following

variables:

X1 = Number of pieces of mail processed (open, sort, etc.)

X2 = Number of money orders and gift certificates sold,

X3 = Number of window payments (customer charge accounts) transacted ,

X4 = Number of change order transactions processed ,

X5 = Number of checks cashed ,

X6 =Number of pieces of miscellaneous mail processed on an ‘’as available” basis , and

X7 =Number of bus tickets sold

The data are provided in **CLERICAL.csv** file count for these activities on each of 52 working days. Conduct a Stepwise Regression Procedure and All-Possible-Regressions procedure of the data using R software package.

APPROACH ONE: TRY TO BUILD A “BEST MODEL” MANUALLY

1. Fit the model with all terms thought to be important as below in `firstordermodel`.
2. Remove terms that are not significant with individual t-tests, this becomes `model`.
3. Conduct a partial F test using `anova()` to determine if this was justified.

```r
workhours=read.csv("CLERICAL.csv",header = TRUE)
firstordermodel<-lm(Y~X1+X2+X3+X4+X5+X6+X7,data=workhours)
summary(firstordermodel)
```

```
##
## Call:
## lm(formula = Y ~ X1 + X2 + X3 + X4 + X5 + X6 + X7, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -18.537  -7.038  -1.224   6.168  28.012
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 60.5537920  9.4952130   6.377  9.4e-08 ***
## X1           0.0013496  0.0009168   1.472  0.14813
## X2           0.0872715  0.0482561   1.809  0.07736 .
## X3           0.0086879  0.0091681   0.948  0.34850
## X4          -0.0427781  0.0173449  -2.466  0.01762 *
## X5           0.0467902  0.0119808   3.905  0.00032 ***
## X6           0.2092130  0.1302236   1.607  0.11530
## X7           0.0048192  0.0055105   0.875  0.38657
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 10.99 on 44 degrees of freedom
## Multiple R-squared:  0.5684, Adjusted R-squared:  0.4997
## F-statistic: 8.277 on 7 and 44 DF,  p-value: 2.053e-06
```

```
model<-lm(Y~X2+X4+X5,data=workhours)
summary(model)
```

```
##
## Call:
## lm(formula = Y ~ X2 + X4 + X5, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -21.259  -9.075  -1.938   6.882  29.303
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 77.725640   6.910199  11.248 4.69e-15 ***
## X2           0.136264   0.045413   3.001  0.00426 **
## X4          -0.034689   0.017140  -2.024  0.04857 *
## X5           0.058268   0.009714   5.998 2.52e-07 ***
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.54 on 48 degrees of freedom
## Multiple R-squared:  0.4806, Adjusted R-squared:  0.4481
## F-statistic:  14.8 on 3 and 48 DF,  p-value: 5.91e-07
```

```
anova(model,firstordermodel)
```

```
## Analysis of Variance Table
##
## Model 1: Y ~ X2 + X4 + X5
## Model 2: Y ~ X1 + X2 + X3 + X4 + X5 + X6 + X7
##   Res.Df    RSS Df Sum of Sq      F  Pr(>F)
## 1     48 6395.3
## 2     44 5314.5  4    1080.8 2.2371 0.08035 .
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
```

4. The Partial F indicates removal of those terms was justifiable (strictly using $\alpha = 0.05$). So determine whether it is justifiable to add two-way interactions across all main effects found in `firstordermodel`.

```
#Model1
interactmodel1<-lm(Y~(X2+X4+X5)^2, data=workhours)
summary(interactmodel1)
```

```
##
## Call:
## lm(formula = Y ~ (X2 + X4 + X5)^2, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -20.734  -8.232  -1.018   7.021  28.770
##
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)
## (Intercept)  6.598e+01  2.199e+01   3.000  0.00439 **
## X2           2.040e-01  1.840e-01   1.108  0.27363
## X4          -2.027e-02  6.819e-02  -0.297  0.76759
## X5           8.380e-02  4.244e-02   1.975  0.05444 .
## X2:X4        1.241e-04  4.965e-04   0.250  0.80382
## X2:X5       -1.712e-04  3.313e-04  -0.517  0.60789
## X4:X5       -4.323e-05  9.246e-05  -0.468  0.64238
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.87 on 45 degrees of freedom
## Multiple R-squared:  0.485,  Adjusted R-squared:  0.4163
## F-statistic: 7.063 on 6 and 45 DF,  p-value: 2.43e-05
```

5. Interactions don’t appear to improve anything, so let’s go back to the model with only first-order effects among the variables identified as significant on an individual *t*-test.

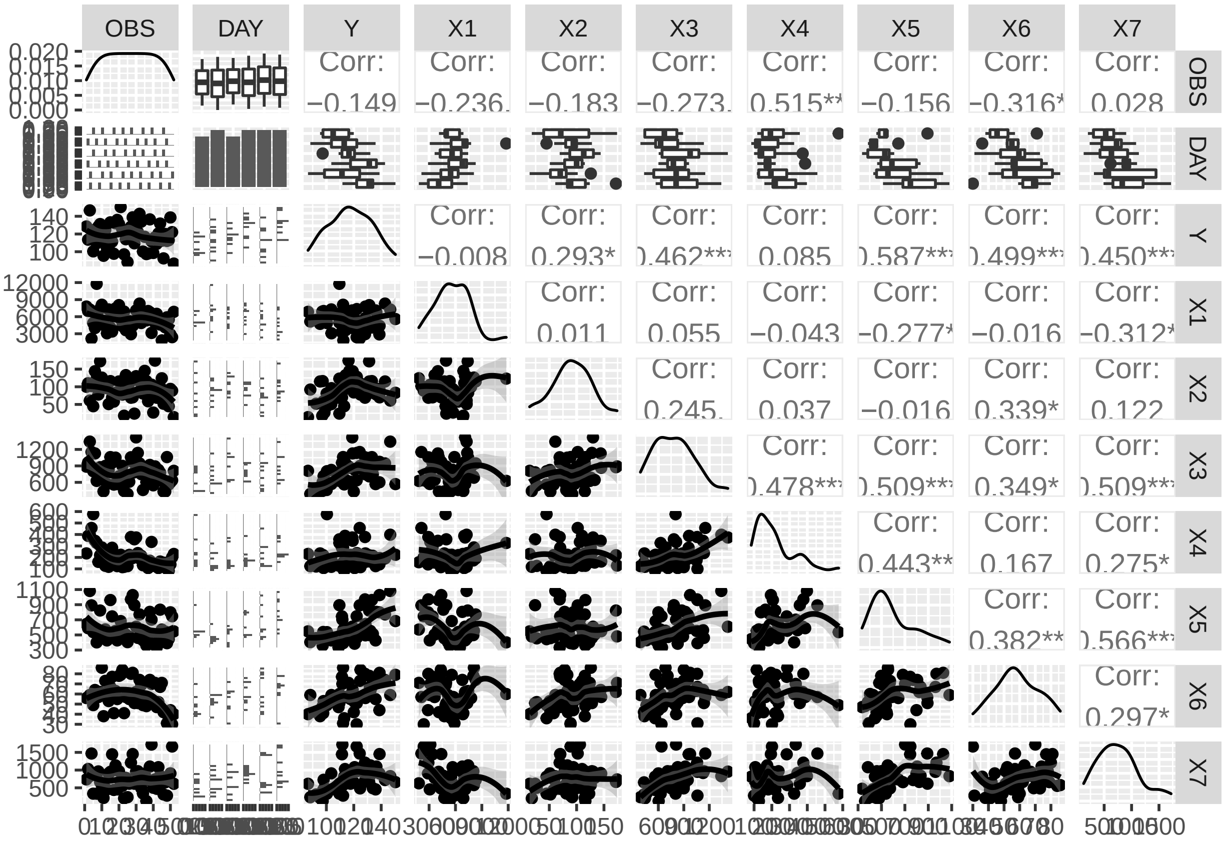
```
bestmodel1<-lm(Y~X2+X4+X5, data=workhours)
summary(bestmodel1)
```

```
##
## Call:
## lm(formula = Y ~ X2 + X4 + X5, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -21.259  -9.075  -1.938   6.882  29.303
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 77.725640   6.910199  11.248 4.69e-15 ***
## X2           0.136264   0.045413   3.001  0.00426 **
## X4          -0.034689   0.017140  -2.024  0.04857 *
## X5           0.058268   0.009714   5.998 2.52e-07 ***
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.54 on 48 degrees of freedom
## Multiple R-squared:  0.4806, Adjusted R-squared:  0.4481
## F-statistic:  14.8 on 3 and 48 DF,  p-value: 5.91e-07
```

6. Now let's check if we can improve the model with *higher-order* terms. We should look to see which terms we might target optimally for potential curvilinearity (i.e., plots with Y against each of $X1...X7$). It looks as if $X2$ and $X5$ are worth trying. So let's do them separately as `bestmodel11` and `bestmodel12`

```
#Improving model Individual T test
library(GGally)

ggpairs(workhours,lower = list(continuous = "smooth_loess", combo =
 "facethist", discrete = "facetbar", na = "na"))
```



```
bestmodel11<-lm(Y~X2+I(X2^2)+X4+X5, data=workhours)
summary(bestmodel11)
```

```
##
## Call:
## lm(formula = Y ~ X2 + I(X2^2) + X4 + X5, data = workhours)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -24.315   -6.480    1.185    5.320   26.482
##
## Coefficients:
```

```
##                Estimate Std. Error t value Pr(>|t|)    
## (Intercept) 61.0933183  8.7297596   6.998 8.22e-09 ***
## X2           0.5762076  0.1611431   3.576 0.000821 ***
## I(X2^2)     -0.0024326  0.0008596  -2.830 0.006827 ** 
## X4          -0.0326852  0.0160268  -2.039 0.047054 *  
## X5           0.0571700  0.0090822   6.295 9.62e-08 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 10.78 on 47 degrees of freedom
## Multiple R-squared:  0.5562, Adjusted R-squared:  0.5184 
## F-statistic: 14.73 on 4 and 47 DF,  p-value: 7.196e-08
```

```
bestmodel12<-lm(Y~X2+I(X2^2)+X4+X5+I(X5^2), data=workhours)
summary(bestmodel12)
```

```
## 
## Call:
## lm(formula = Y ~ X2 + I(X2^2) + X4 + X5 + I(X5^2), data = workhours)
## 
## Residuals:
##      Min       1Q   Median       3Q      Max 
## -23.5578  -6.9145   0.8808   5.8568  25.3756 
## 
## Coefficients:
##                Estimate Std. Error t value Pr(>|t|)    
## (Intercept)  5.097e+01  2.059e+01   2.475 0.017051 *  
## X2           5.802e-01  1.625e-01   3.570 0.000849 ***
## I(X2^2)     -2.479e-03  8.703e-04  -2.848 0.006548 ** 
## X4          -3.358e-02  1.623e-02  -2.069 0.044214 *  
## X5           9.044e-02  6.187e-02   1.462 0.150604    
## I(X5^2)     -2.425e-05  4.459e-05  -0.544 0.589264    
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
## 
## Residual standard error: 10.86 on 46 degrees of freedom
## Multiple R-squared:  0.559,  Adjusted R-squared:  0.5111 
## F-statistic: 11.66 on 5 and 46 DF,  p-value: 2.612e-07
```

APPROACH 2: Use Stepwise regression

1. Run a stepwise regression on the additive model with all potential terms. Note, we have `details=FALSE` here, and the output of the stepwise only is shown.

```
#_Stepwise Method_
library(olsrr) #need to install the package olsrr
```

```
## Warning: package 'olsrr' was built under R version 4.2.2
```

```
## 
## Attaching package: 'olsrr'
## The following object is masked from 'package:datasets':
##
##     rivers
```

```
library(leaps) #need to install the package leaps for best.subset() function
```

```
## Warning: package 'leaps' was built under R version 4.2.2
```

```
workhours=read.csv("CLERICAL.csv",header = TRUE)

#Using Stepwise Regression Procedure for data selection
firstordermodel<-lm(Y~X1+X2+X3+X4+X5+X6+X7,data=workhours)
step <- ols_step_both_p(firstordermodel,pent = 0.1, prem = 0.3, details=FALSE)
summary(step$model)
```

```
##
## Call:
## lm(formula = paste(response, "~", paste(preds, collapse = " + ")),
##     data = l)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -22.7666  -8.3861  -0.4456   8.5525  25.9007
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 70.44910    7.72424   9.121 5.73e-12 ***
## X5           0.05075    0.01024   4.957 9.73e-06 ***
## X2           0.10212    0.04766   2.143   0.0373 *
## X4          -0.03398    0.01669  -2.036   0.0474 *
## X6           0.25226    0.13168   1.916   0.0615 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.23 on 47 degrees of freedom
## Multiple R-squared:  0.5182, Adjusted R-squared:  0.4772
## F-statistic: 12.64 on 4 and 47 DF,  p-value: 4.647e-07
```

2. Take the output of stepwise regression and see if two-way interaction terms are justifiable. The first attempt `interactmodel2` shows that there *may be a chance that* ***X2:X6*** might remain significant when added to the first-order model with just main effects. So let's try just that in `bestmodel21`, but we find that it doesn't work that well as the $P > \alpha$ (i.e. 0.05), so let's go back to just the main effects in `bestmodel22`.

```
library(olsrr) #need to install the package olsrr
library(leaps) #need to install the package leaps for best.subset() function
workhours=read.csv("CLERICAL.csv",header = TRUE)

#Model2
mod2=lm(Y~X2+X4+X5+X6, data=workhours)
interactmodel2<-lm(Y~(X2+X4+X5+X6)^2, data=workhours)
summary(interactmodel2)
```

```
##
## Call:
## lm(formula = Y ~ (X2 + X4 + X5 + X6)^2, data = workhours)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -25.1071  -7.0977  -0.5452   6.9982  23.7102
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  2.861e+00  3.921e+01   0.073   0.9422
## X2           5.175e-01  2.785e-01   1.858   0.0704 .
## X4          -5.762e-02  9.360e-02  -0.616   0.5416
## X5           1.071e-01  6.585e-02   1.626   0.1116
## X6           1.571e+00  7.092e-01   2.216   0.0323 *
## X2:X4       -9.526e-05  5.644e-04  -0.169   0.8668
## X2:X5        1.425e-04  3.411e-04   0.418   0.6783
## X2:X6       -8.931e-03  4.503e-03  -1.983   0.0541 .
## X4:X5       -2.535e-05  9.734e-05  -0.260   0.7958
## X4:X6        7.972e-04  1.984e-03   0.402   0.6899
## X5:X6       -1.100e-03  8.586e-04  -1.282   0.2071
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.41 on 41 degrees of freedom
## Multiple R-squared:  0.5661, Adjusted R-squared:  0.4603
## F-statistic: 5.349 on 10 and 41 DF,  p-value: 5.085e-05
```

```
bestmodel21<-lm(Y~X2+X4+X5+X6+X2*X6, data=workhours)
summary(bestmodel21)
```

```
##
## Call:
## lm(formula = Y ~ X2 + X4 + X5 + X6 + X2 * X6, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -24.364  -7.618  -0.616   7.252  24.350
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept) 40.296332  19.291735   2.089   0.0423 *
## X2           0.474925   0.224291   2.117   0.0397 *
## X4          -0.033759   0.016362  -2.063   0.0448 *
## X5           0.047836   0.010183   4.698  2.4e-05 ***
## X6           0.841726   0.370116   2.274   0.0277 *
## X2:X6       -0.006664   0.003922  -1.699   0.0960 .
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.02 on 46 degrees of freedom
## Multiple R-squared:  0.5467, Adjusted R-squared:  0.4974
## F-statistic: 11.09 on 5 and 46 DF,  p-value: 4.785e-07
```

```
bestmodel22<-lm(Y~X2+X4+X5+X6, data=workhours)
summary(bestmodel22)
```

```
##
## Call:
## lm(formula = Y ~ X2 + X4 + X5 + X6, data = workhours)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -22.7666  -8.3861  -0.4456   8.5525  25.9007
##
## Coefficients:
##             Estimate Std. Error t value Pr(>|t|)
## (Intercept) 70.44910    7.72424   9.121 5.73e-12 ***
## X2           0.10212    0.04766   2.143   0.0373 *
## X4          -0.03398    0.01669  -2.036   0.0474 *
## X5           0.05075    0.01024   4.957 9.73e-06 ***
## X6           0.25226    0.13168   1.916   0.0615 .
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 11.23 on 47 degrees of freedom
## Multiple R-squared:  0.5182, Adjusted R-squared:  0.4772
## F-statistic: 12.64 on 4 and 47 DF,  p-value: 4.647e-07
```

3. Now let's see if it is justifiable to add any second-order terms. We'll let you look back about at the `ggpairs()` plot. We think (this time) that $X2$ and $X6$ might be good candidates to be non-linear terms, given that we found that $X5$ wasn't so great last time. But this is really just a guess. And this time we find that $X2$ was justified, but not $X6$ as a quadratic (i.e., as \$X2ˆ2\$). But we'd probably want to re-run with $X6$ `bestmodel23`.

```
#Improving model from Stepwise method
library(olsrr) #need to install the package olsrr
library(GGally) # need toinstall the GGally package for ggpairs function

workhours=read.csv("CLERICAL.csv",
                header = TRUE)

#ggpairs(workhours,lower = list(continuous = "smooth_loess", combo =
# "facethist", discrete = "facetbar", na = "na"))


bestmodel21<-lm(Y~X2+I(X2^2)+X4+X5+X6+I(X6^2), data=workhours)
summary(bestmodel21)
```

```
##
## Call:
## lm(formula = Y ~ X2 + I(X2^2) + X4 + X5 + X6 + I(X6^2), data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -25.980  -6.680   1.176   6.473  23.328
```

```
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 45.9256582 24.9048015   1.844  0.07177 .
## X2           0.5160220  0.1643950   3.139  0.00299 **
## I(X2^2)     -0.0022744  0.0008637  -2.633  0.01154 *
## X4          -0.0337748  0.0162257  -2.082  0.04310 *
## X5           0.0517135  0.0098304   5.261 3.85e-06 ***
## X6           0.5867189  0.8456851   0.694  0.49139
## I(X6^2)     -0.0032293  0.0071060  -0.454  0.65169
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 10.68 on 45 degrees of freedom
## Multiple R-squared:  0.5829, Adjusted R-squared:  0.5273
## F-statistic: 10.48 on 6 and 45 DF,  p-value: 2.967e-07
```

```
bestmodel22<-lm(Y~X2+I(X2^2)+X4+X5+X6, data=workhours)
summary(bestmodel22)
```

```
##
## Call:
## lm(formula = Y ~ X2 + I(X2^2) + X4 + X5 + X6, data = workhours)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -25.3063  -7.4222  -0.0186   6.2710  23.4825
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 56.4607725  9.0226268   6.258 1.19e-07 ***
## X2           0.5130400  0.1628411   3.151  0.00286 **
## I(X2^2)     -0.0022381  0.0008525  -2.625  0.01171 *
## X4          -0.0322631  0.0157435  -2.049  0.04616 *
## X5           0.0510943  0.0096512   5.294 3.26e-06 ***
## X6           0.2067173  0.1253390   1.649  0.10591
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 10.59 on 46 degrees of freedom
## Multiple R-squared:  0.581,  Adjusted R-squared:  0.5354
## F-statistic: 12.76 on 5 and 46 DF,  p-value: 8.518e-08
```

```
bestmodel23<-lm(Y~X2+I(X2^2)+X4+X5, data=workhours)
summary(bestmodel23)
```

```
##
## Call:
## lm(formula = Y ~ X2 + I(X2^2) + X4 + X5, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -24.315  -6.480   1.185   5.320  26.482
```

```
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept) 61.0933183  8.7297596   6.998 8.22e-09 ***
## X2           0.5762076  0.1611431   3.576 0.000821 ***
## I(X2^2)     -0.0024326  0.0008596  -2.830 0.006827 **
## X4          -0.0326852  0.0160268  -2.039 0.047054 *
## X5           0.0571700  0.0090822   6.295 9.62e-08 ***
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 10.78 on 47 degrees of freedom
## Multiple R-squared:  0.5562, Adjusted R-squared:  0.5184
## F-statistic: 14.73 on 4 and 47 DF,  p-value: 7.196e-08
```

APPROACH THREE: Use all-best-subsets regression.

1. Run an all-best subsets regression using `regsubsets()`, and thenn combine the salient model selection diagnostics into a single table to display using `cbind()`.

```
#Using All possible Regression
library(olsrr) #need to install the package olsrr
library(leaps) #need to install the package leaps for best.subset() function


workhours=read.csv("CLERICAL.csv",
                header = TRUE)

#option 2
best.subset<-regsubsets(Y~X1+X2+X3+X4+X5+X6+X7, data= workhours)
summary(best.subset)
```

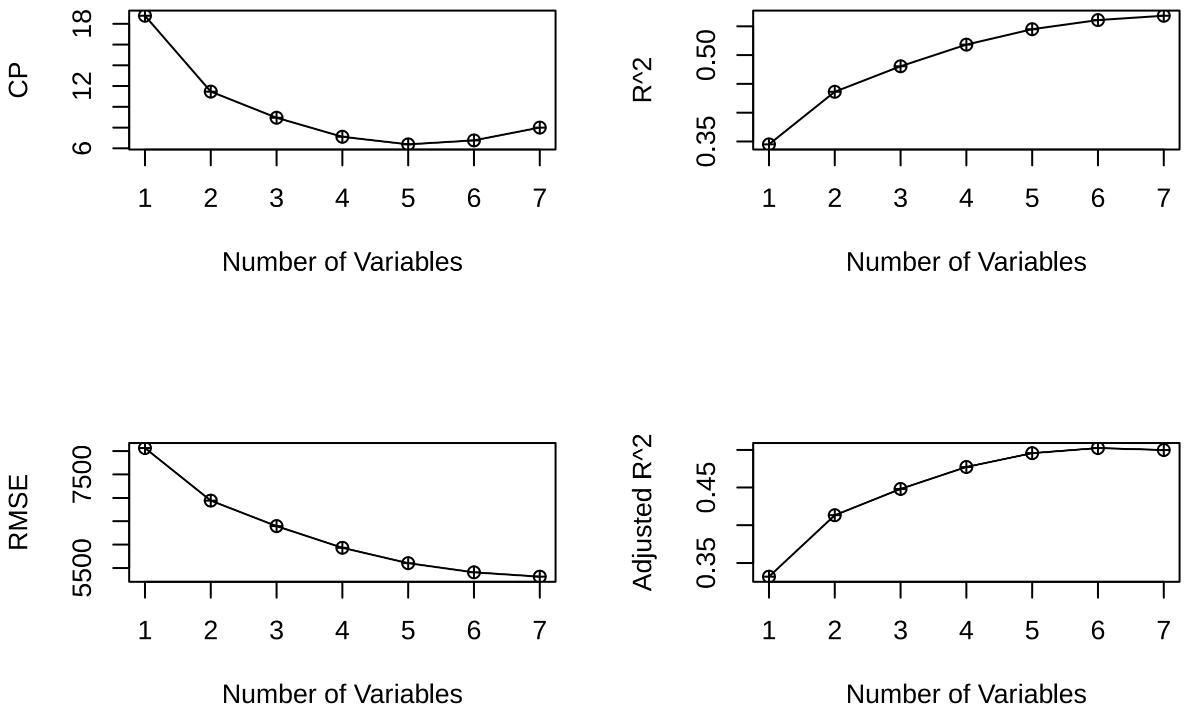
```
## Subset selection object
## Call: regsubsets.formula(Y ~ X1 + X2 + X3 + X4 + X5 + X6 + X7, data = workhours)
## 7 Variables  (and intercept)
##    Forced in Forced out
## X1     FALSE      FALSE
## X2     FALSE      FALSE
## X3     FALSE      FALSE
## X4     FALSE      FALSE
## X5     FALSE      FALSE
## X6     FALSE      FALSE
## X7     FALSE      FALSE
## 1 subsets of each size up to 7
## Selection Algorithm: exhaustive
##          X1  X2  X3  X4  X5  X6  X7
## 1  ( 1 ) " " " " " " " " "*" " " " "
## 2  ( 1 ) " " "*" " " " " "*" " " " "
## 3  ( 1 ) " " "*" " " "*" "*" " " " "
## 4  ( 1 ) " " "*" " " "*" "*" "*" " "
## 5  ( 1 ) " " "*" "*" "*" "*" "*" " "
## 6  ( 1 ) "*" "*" "*" "*" "*" "*" " "
## 7  ( 1 ) "*" "*" "*" "*" "*" "*" "*"
```

```r
reg.summary<-summary(best.subset)
rsquare<-c(reg.summary$rsq)
cp<-c(reg.summary$cp)
AdjustedR<-c(reg.summary$adjr2)
RMSE<-c(reg.summary$rss)

## Display model selection diagnostics we just aggregated
cbind(rsquare,cp,RMSE,AdjustedR)
```

```
##        rsquare        cp     RMSE AdjustedR
## [1,] 0.3449436 18.775229 8065.390 0.3318425
## [2,] 0.4362622 11.466378 6941.028 0.4132525
## [3,] 0.4805843  8.948273 6395.312 0.4481208
## [4,] 0.5182013  7.113662 5932.152 0.4771972
## [5,] 0.5449760  6.384302 5602.489 0.4955168
## [6,] 0.5608627  6.764836 5406.883 0.5023111
## [7,] 0.5683657  8.000000 5314.503 0.4996966
```

```r
## Plot these (if it helps).
par(mfrow=c(2,2)) # split the plotting panel into a 2 x 2 grid
plot(reg.summary$cp,type = "o",pch=10, xlab="Number of Variables",ylab= "CP")
plot(reg.summary$rsq,type = "o",pch=10, xlab="Number of Variables",ylab= "R^2")
plot(reg.summary$rss,type = "o",pch=10, xlab="Number of Variables",ylab= "RMSE")
plot(reg.summary$adjr2,type = "o",pch=10, xlab="Number of Variables",ylab= "Adjusted R^2")
```



2. We decide, using our favourite diagnostic (or diagnostics) let’s say, that the model with 6 terms (i.e., `[6,]` on the sixth row, is the best choice. So let’s move it forward and see if any two-way interactions are justified. They are! So let’s add just those two interactions (i.e.,`X1:X6` and `X2:X6`) into the original first-order model and see if they stay significant. They do. So let’s move it forward.

```
workhours=read.csv("CLERICAL.csv",header = TRUE)
mod3=lm(Y~X1+X2+X3+X4+X5+X6, data=workhours)
interactmodel3<-lm(Y~(X1+X2+X3+X4+X5+X6)^2, data=workhours)
summary(interactmodel3)
```

```
##
## Call:
## lm(formula = Y ~ (X1 + X2 + X3 + X4 + X5 + X6)^2, data = workhours)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -19.1807  -5.3442   0.7369   4.1799  21.0237
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  1.109e+01  8.736e+01   0.127   0.8998
## X1          -3.470e-03  8.140e-03  -0.426   0.6729
## X2           1.185e+00  5.544e-01   2.137   0.0409 *
## X3           7.461e-02  8.003e-02   0.932   0.3587
## X4          -2.598e-01  1.822e-01  -1.425   0.1644
## X5           3.511e-02  1.011e-01   0.347   0.7308
## X6           6.822e-01  1.256e+00   0.543   0.5911
## X1:X2       -7.714e-05  5.982e-05  -1.289   0.2071
## X1:X3       -6.290e-06  8.452e-06  -0.744   0.4626
## X1:X4        1.875e-05  1.762e-05   1.064   0.2959
## X1:X5        2.033e-06  8.322e-06   0.244   0.8087
## X1:X6        2.140e-04  1.069e-04   2.002   0.0544 .
## X2:X3        3.022e-04  4.404e-04   0.686   0.4979
## X2:X4       -1.179e-03  8.281e-04  -1.423   0.1649
## X2:X5        5.483e-04  4.720e-04   1.162   0.2545
## X2:X6       -1.791e-02  6.934e-03  -2.583   0.0149 *
## X3:X4        8.826e-05  1.580e-04   0.559   0.5806
## X3:X5       -1.071e-04  9.664e-05  -1.108   0.2767
## X3:X6       -2.485e-04  8.660e-04  -0.287   0.7761
## X4:X5        1.460e-04  2.460e-04   0.594   0.5572
## X4:X6        1.135e-03  2.471e-03   0.459   0.6492
## X5:X6        1.667e-04  1.318e-03   0.126   0.9002
## ---
## Signif. codes:  0 ’***’ 0.001 ’**’ 0.01 ’*’ 0.05 ’.’ 0.1 ’ ’ 1
##
## Residual standard error: 11.16 on 30 degrees of freedom
## Multiple R-squared:  0.6967, Adjusted R-squared:  0.4844
## F-statistic: 3.281 on 21 and 30 DF,  p-value: 0.001509
```

```
bestmodel3<-lm(Y~X1+X2+X3+X4+X5+X6+X2*X6+X1*X6, data=workhours)
summary(bestmodel3)
```

```
##
```

```
## Call:
## lm(formula = Y ~ X1 + X2 + X3 + X4 + X5 + X6 + X2 * X6 + X1 *
##     X6, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -20.232  -6.195  -0.924   4.847  25.003
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.560e+01  2.893e+01   2.613 0.012315 *
## X1          -8.461e-03  4.249e-03  -1.992 0.052799 .
## X2           5.103e-01  2.116e-01   2.411 0.020255 *
## X3           1.676e-02  8.466e-03   1.980 0.054173 .
## X4          -4.627e-02  1.598e-02  -2.896 0.005922 **
## X5           4.031e-02  1.109e-02   3.635 0.000738 ***
## X6           1.604e-01  4.596e-01   0.349 0.728758
## X2:X6       -8.283e-03  3.686e-03  -2.247 0.029832 *
## X1:X6        1.578e-04  6.641e-05   2.376 0.022012 *
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 10.11 on 43 degrees of freedom
## Multiple R-squared:  0.643,  Adjusted R-squared:  0.5766
## F-statistic: 9.681 on 8 and 43 DF,  p-value: 1.492e-07
```

3. And finally, let's see if we can justify any higher-order terms on these. We saw earlier, of course, that $X2^2$ might be justified. So let's give it a go. Perhaps we out to leave out $X1$ and \$X6\$. Have a look at a the R^2_{adj} and see if you can come to your own decision.

```
#Improving model from best subset function
library(GGally) # need toinstall the GGally package for ggpairs function

workhours=read.csv("CLERICAL.csv",header = TRUE)

#ggpairs(workhours)
#pairs(~Y+X1+X2+X3+X4+X5+X6+X7,data=workhours)


bestmodel31<-lm(Y~X1+X2+I(X2^2)+X3+X4+X5+X6+X1*X6, data=workhours)
summary(bestmodel31)
```

```
##
## Call:
## lm(formula = Y ~ X1 + X2 + I(X2^2) + X3 + X4 + X5 + X6 + X1 *
##     X6, data = workhours)
##
## Residuals:
##     Min      1Q  Median      3Q     Max
## -20.559  -6.328  -0.694   5.042  25.934
##
## Coefficients:
##               Estimate Std. Error t value Pr(>|t|)
## (Intercept)  7.927e+01  2.636e+01   3.007 0.004397 **
## X1          -4.913e-03  4.299e-03  -1.143 0.259355
## X2           4.779e-01  1.645e-01   2.906 0.005766 **
## I(X2^2)     -2.273e-03  8.318e-04  -2.733 0.009074 **
## X3           1.597e-02  8.276e-03   1.930 0.060187 .
## X4          -4.489e-02  1.561e-02  -2.877 0.006228 **
## X5           4.657e-02  1.089e-02   4.278 0.000103 ***
## X6          -3.455e-01  3.466e-01  -0.997 0.324476
## X1:X6        1.022e-04  6.652e-05   1.536 0.131967
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 9.865 on 43 degrees of freedom
## Multiple R-squared:  0.6601, Adjusted R-squared:  0.5969
## F-statistic: 10.44 on 8 and 43 DF,  p-value: 5.581e-08
```