Homework 2

Shun-Lung Chang, Dilip Hiremath

```
load("data/OregonHomes.Rdata") # read the data into R
```

1. First of all, read the data file OregonHomes.Rdata (the data frame is called homes) and load the libraries you typically use. Create a new variable that groups the garage size information into two classes: one for garage size for no or one car, the second one for garage sizes for two or more cars.[hint: There are multiple ways to do this. E.g., using the cut command or the command recode from the car package.]

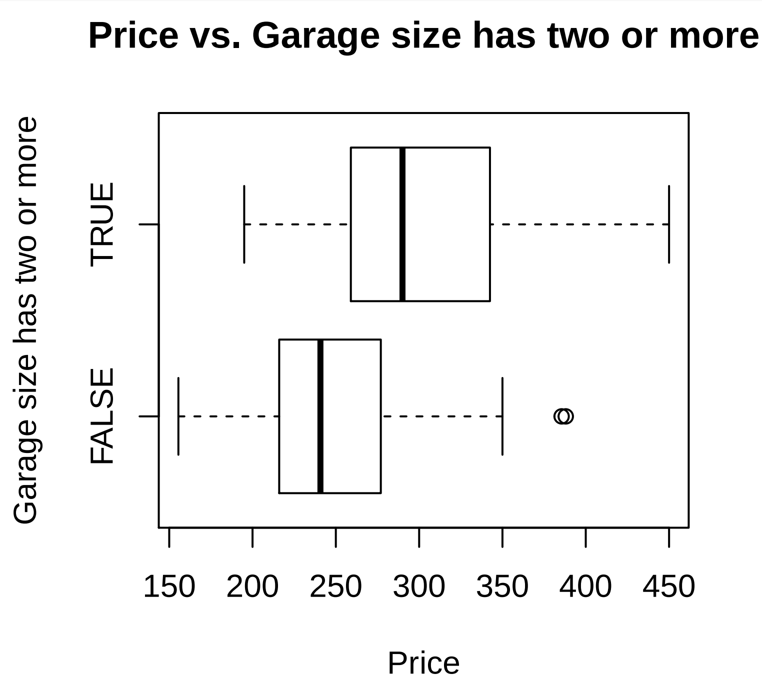
Generate a boxplot for the house prices grouped by the newly created garage size groups.

```
homes$two_cars_more <- homes$Gar >= 2
```

(a) (1 point) Based on the box plot, do you expect that the mean house price differs significantly between the two groups?

As the plot indicates, the mean house price between two groups may differ significantly given the high differece (approximately 45).

```
boxplot(Price ~ two_cars_more,
        data = homes,
        main = "Price vs. Garage size has two or more",
        xlab = "Price",
        ylab = "Garage size has two or more",
        horizontal = TRUE)
```



(b) (half a point) Using a t-test assuming equal variances assess whether there is a significant difference in house prices between the two groups.

Considering a significance level of 5%, the p-value in the test is small enough to conclude that the house price in two groups are not equal.

```r
t.test(Price ~ two_cars_more, data = homes, var.equal = TRUE)
```

```
    Two Sample t-test

data:  Price by two_cars_more
t = -3.2878, df = 74, p-value = 0.001547
alternative hypothesis: true difference in means is not equal to 0
95 percent confidence interval:
 -73.93064 -18.13474
sample estimates:
mean in group FALSE  mean in group TRUE
           254.3000            300.3327
```

(c) (half a point) Check whether equality of variance is actually given?

Given the large p-value we can say the assumption of equal variance holds.

```r
var.test(Price ~ two_cars_more, data = homes)
```

```
    F test to compare two variances

data:  Price by two_cars_more
F = 1.2901, num df = 23, denom df = 51, p-value = 0.4427
alternative hypothesis: true ratio of variances is not equal to 1
95 percent confidence interval:
 0.6652745 2.7534679
sample estimates:
ratio of variances
          1.290124
```

2. Run a one-way ANOVA-test (command aov to assess whether there is a significant difference in house prices between the two groups.

```r
aov_fit <- aov(Price ~ two_cars_more, data = homes)
summary(aov_fit)
```

```
              Df Sum Sq Mean Sq F value  Pr(>F)
two_cars_more  1  34796   34796   10.81 0.00155
Residuals     74 238211    3219
1 observation deleted due to missingness
```

(a) (half a point) Based on the one-way ANOVA-test is there a significant difference in house prices between the two groups.

(b) (half a point) Assess by using a linear model whether there is a significant difference in house prices between the two groups.

```r
mod_1 <- lm(Price ~ two_cars_more, data = homes)
summary(mod_1)
```

```
Call:
lm(formula = Price ~ two_cars_more, data = homes)

Residuals:
    Min      1Q  Median      3Q     Max
-105.33  -39.81  -13.55   39.59  149.67

Coefficients:
                  Estimate Std. Error t value Pr(>|t|)
(Intercept)         254.30      11.58  21.958  < 2e-16
two_cars_moreTRUE    46.03      14.00   3.288  0.00155

Residual standard error: 56.74 on 74 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.1275,	Adjusted R-squared:  0.1157
F-statistic: 10.81 on 1 and 74 DF,  p-value: 0.001547
```

(c) (1 point) Compare the results of the t-test, the linear model and the ANOVA. How do the p-values of the three tests relate to each other? How do the test statistics of the three tests relate to each other?

3. Using the variable Gar as a factor, run an ANOVA model to see whether the garage size has a statistically significant impact on the average house price.

```r
aov_fit <- aov(Price ~ as.factor(Gar), data = homes)
summary(aov_fit)
```

```
               Df Sum Sq Mean Sq F value Pr(>F)
as.factor(Gar)  3  36682   12227   3.725  0.015
Residuals      72 236325    3282
1 observation deleted due to missingness
```

(a) (half a point) Does the test result indicate that garage size has a statistically significant impact on house prices? Report the observed p-value for the overall ANOVA test!

(b) (half a point) Use the Tukey HSD post hoc test to determine for which garage sizes average house prices differ significantly at the 5% significance level.

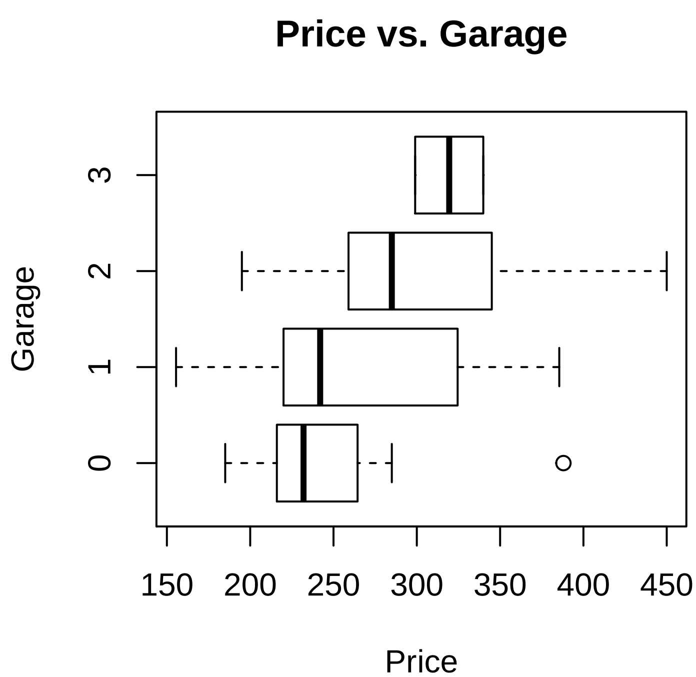
```r
TukeyHSD(aov_fit, ordered = TRUE, conf.level = 0.95)
```

```
  Tukey multiple comparisons of means
```

```
    95% family-wise confidence level
    factor levels have been ordered

Fit: aov(formula = Price ~ as.factor(Gar), data = homes)

$`as.factor(Gar)`
        diff        lwr       upr     p adj
1-0 13.74545 -47.983945  75.47485 0.9361062
2-0 52.71345   2.532603 102.89431 0.0357791
3-0 72.59545 -43.232873 188.42378 0.3585166
2-1 38.96800  -7.942282  85.87828 0.1372769
3-1 58.85000 -55.599370 173.29937 0.5330866
3-2 19.88200 -88.774603 128.53860 0.9630134
```

(c) (1 point) Can you explain why the average house price for homes with garages for 2 cars is signficantly different from the average house price for homes without garage (garage with car size 0) while the average house price for homes with garages for 3 cars is NOT signficantly different from the average house price for homes without garage (garage with car size 0) despite the fact that the average house price for homes with garages for three cars is larger than the one for homes with garages for two cars.

```r
boxplot(Price ~ Gar, data = homes,
        main = 'Price vs. Garage',
        xlab = 'Price',
        ylab = 'Garage',
        horizontal = TRUE)
```



4. Now, you build a linear model for the house price based on all predictor variables in the original data set (So, please do not include the newly created grouping variable for the garage size).

```
mod_2 <- lm(Price ~ . - two_cars_more, data = homes)
```

(a) (1 point) According to this model and using the ANOVA table, which predictors have a signfifcant impact on the average house price at the 5% significance level?

```
summary(mod_2)
```

```
Call:
lm(formula = Price ~ . - two_cars_more, data = homes)

Residuals:
    Min      1Q  Median      3Q     Max 
-94.978 -28.849  -0.511  24.350  94.094 

Coefficients: (1 not defined because of singularities)
                Estimate Std. Error t value Pr(>|t|)
(Intercept)    -202.1596   660.5569  -0.306  0.76061
ID               -0.2662     0.2796  -0.952  0.34495
Floor            80.3028    32.0373   2.507  0.01487
Lot              10.3434     3.6717   2.817  0.00652
Bath              4.4336    11.7998   0.376  0.70842
Bed             -12.9997     9.1684  -1.418  0.16131
Year              0.1604     0.3352   0.479  0.63396
Age                   NA         NA      NA       NA
Gar               6.1577     9.6116   0.641  0.52414
StatusPending   -17.8892    16.5880  -1.078  0.28508
StatusSold      -37.3573    13.9762  -2.673  0.00963
SchoolCrest      12.4545    36.1419   0.345  0.73158
SchoolEdison     91.7660    31.7622   2.889  0.00534
SchoolHarris     61.9000    33.0168   1.875  0.06561
SchoolParker     -6.9931    31.0327  -0.225  0.82246
SchoolRedwood    13.0448    30.4176   0.429  0.66954

Residual standard error: 45.03 on 61 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.5468,    Adjusted R-squared:  0.4428 
F-statistic: 5.258 on 14 and 61 DF,  p-value: 0.000002202
```

(b) (half a point) How good does the model fit?

(c) (half a point) In which form is the variable Gar included in this model? As a factor or as a numeric variable? How do you see the difference in the output?

```
homes$Gar <- as.factor(homes$Gar)
mod_3 <- lm(Price ~ . - two_cars_more, data = homes)
summary(mod_3)
```

```
Call:
lm(formula = Price ~ . - two_cars_more, data = homes)

Residuals:
     Min       1Q   Median       3Q      Max
-101.644  -26.129    0.759   25.531   94.487

Coefficients: (1 not defined because of singularities)
               Estimate Std. Error t value Pr(>|t|)
(Intercept)   -259.6789   662.9167  -0.392  0.69668
ID              -0.2588     0.2807  -0.922  0.36033
Floor           81.7675    32.1374   2.544  0.01359
Lot             10.8002     3.7055   2.915  0.00502
Bath            -0.4432    12.7816  -0.035  0.97246
Bed            -12.3504     9.5822  -1.289  0.20247
Year             0.2044     0.3373   0.606  0.54687
Age                  NA         NA      NA       NA
Gar1           -20.5876    22.7198  -0.906  0.36854
Gar2             5.7959    20.0789   0.289  0.77385
Gar3             0.8246    46.5716   0.018  0.98593
StatusPending  -16.1670    17.7091  -0.913  0.36500
StatusSold     -37.7953    14.1371  -2.673  0.00969
SchoolCrest     -9.1262    39.9655  -0.228  0.82016
SchoolEdison    76.5241    33.8480   2.261  0.02747
SchoolHarris    48.1638    34.5973   1.392  0.16911
SchoolParker   -25.1866    34.4369  -0.731  0.46744
SchoolRedwood   -4.6595    33.3122  -0.140  0.88924

Residual standard error: 45.1 on 59 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.5605,    Adjusted R-squared:  0.4413
F-statistic: 4.702 on 16 and 59 DF,  p-value: 0.000005733
```

5. (2 points) In the linear model from Question 4 either the line for variable Age or the one for variable Year is empty in the ANOVA table and in the coefficient table all corresponding numbers are marked as NA. Explain why!

$Age = (Year - 1970) \times 0.1$

6. (2 points) Looking at the sign of the (significant) regression coefficients, do the empirically present relationships make sense?

7. (2 points) Starting with a model using all predictors in the data set (except the grouped garage size and the variable Year) use the stepwise automatic model procedure to find the best linear model. Use the backward/forward strategy and the AIC as criterion. Briefly summarize the resulting model!

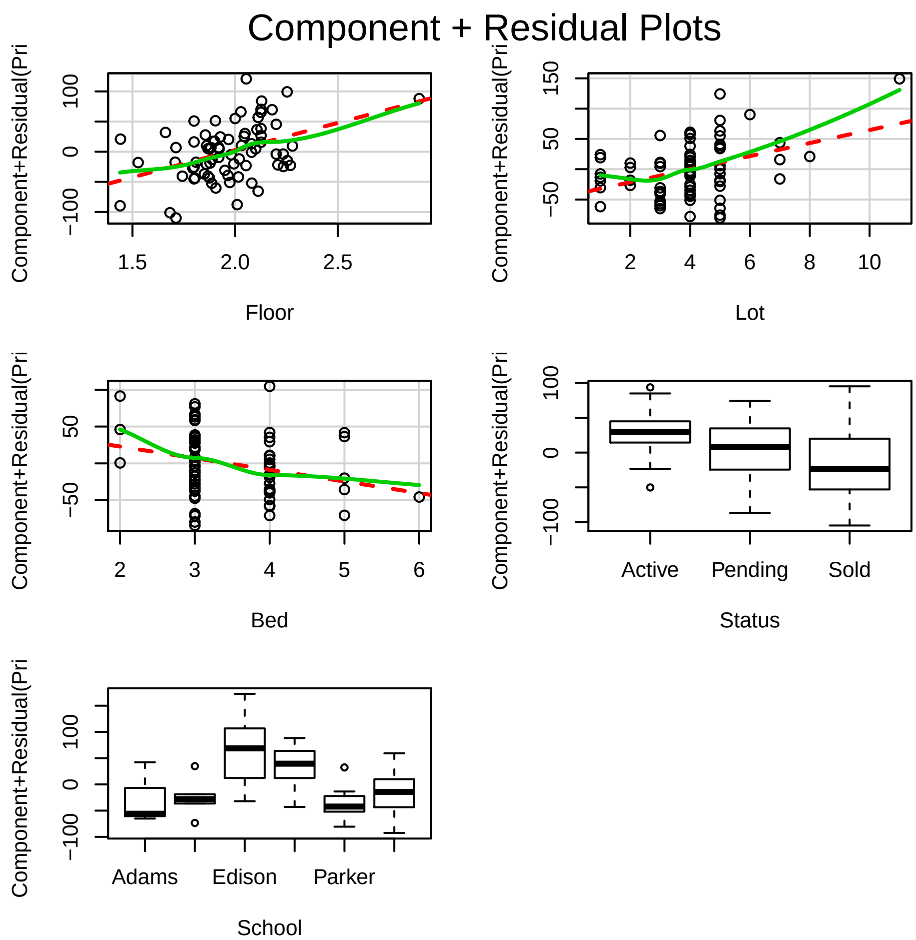
```r
mod_4 <- lm(Price ~ . - two_cars_more - Year, data = homes)
mod_5 <- step(mod_4, direction = "both")
```

```r
summary(mod_5)
```

```

Call:
lm(formula = Price ~ Floor + Lot + Bed + Status + School, data = homes)

Residuals:
    Min      1Q  Median      3Q     Max 
-91.369 -29.241  -0.683  24.312 113.296 

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)    118.459     54.739   2.164  0.03414
Floor           90.214     26.319   3.428  0.00106
Lot             10.754      3.480   3.090  0.00294
Bed            -15.787      8.018  -1.969  0.05323
StatusPending  -20.545     16.227  -1.266  0.20999
StatusSold     -43.293     12.890  -3.359  0.00131
SchoolCrest      1.259     33.763   0.037  0.97036
SchoolEdison    85.616     29.470   2.905  0.00501
SchoolHarris    58.508     29.680   1.971  0.05295
SchoolParker   -11.034     29.546  -0.373  0.71003
SchoolRedwood   11.902     28.145   0.423  0.67377

Residual standard error: 44.54 on 65 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.5277,	Adjusted R-squared:  0.4551 
F-statistic: 7.263 on 10 and 65 DF,  p-value: 0.0000001392
```

8. Draw component/residual plots for all predictors in the final model resulting in the previous task. [hint: the package car contains a command crPlots to draw these plots.]

```r
library(car)
crPlots(mod_5)
```



(a) (half a point) Check whether some quadratic effects should be included.

(b) (half a point) Vary the smoothing parameter to 0.25 and to 0.75. Which parameter setting indicates the quadratic effects more clearly? [hint: Look at the help pages for car::crPlots and check the examples of using the smoothing parameter.]

(c) (1 point) Add at least one quadratic effect to the model and compare the resulting model with the previous one. Is there a sufficient improvement in the model that justifies inclusion of the quadratic effect?

```
mod_6 <- lm(Price ~ Floor + Lot + Bed + Status + School + I(Lot ^ 2), data = homes)
summary(mod_6)
```

```
Call:
lm(formula = Price ~ Floor + Lot + Bed + Status + School + I(Lot^2),
    data = homes)

Residuals:
    Min      1Q  Median      3Q     Max 
-86.520 -27.011  -1.905  27.445 118.260 

Coefficients:
```

```
              Estimate Std. Error t value Pr(>|t|)
(Intercept)   168.3582    58.7639   2.865 0.005635
Floor          79.4582    26.2322   3.029 0.003536
Lot            -7.1028     9.3763  -0.758 0.451513
Bed           -14.7420     7.8456  -1.879 0.064797
StatusPending -21.9238    15.8591  -1.382 0.171651
StatusSold    -45.3581    12.6264  -3.592 0.000637
SchoolCrest    10.2465    33.2594   0.308 0.759024
SchoolEdison   93.5169    29.0337   3.221 0.002009
SchoolHarris   58.1964    28.9808   2.008 0.048857
SchoolParker   -3.4065    29.0906  -0.117 0.907147
SchoolRedwood  18.2384    27.6559   0.659 0.511956
I(Lot^2)        1.8599     0.9103   2.043 0.045145

Residual standard error: 43.49 on 64 degrees of freedom
  (1 observation deleted due to missingness)
Multiple R-squared:  0.5566,    Adjusted R-squared:  0.4804
F-statistic: 7.305 on 11 and 64 DF,  p-value: 0.00000006514
```