Building Regression Models

Vinay Vaida

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BUILDING REGRESSION MODELS FOR PREDICTION

General principles Our general principles for building regression models for prediction are as follows:

1. Include all input variables that, for substantive reasons, might be expected to be important in predicting the outcome.
2. It is not always necessary to include these inputs as separate predictors—for example, sometimes several inputs can be averaged or summed to create a “total score” that can be used as a single predictor in the model.
3. For inputs that have large effects, consider including their interactions as well.
4. We suggest the following strategy for decisions regarding whether to exclude a variable from a prediction model based on expected sign and statistical signifi- cance (typically measured at the 5% level; that is, a coefficient is “statistically significant” if its estimate is more than 2 standard errors from zero):
   1. If a predictor is not statistically significant and has the expected sign, it is generally fine to keep it in. It may not help predictions dramatically but is also probably not hurting them.
   2. If a predictor is not statistically significant and does not have the expected sign (for example, incumbency having a negative effect on vote share), consider removing it from the model (that is, setting its coefficient to zero).
   3. If a predictor is statistically significant and does not have the expected sign, then think hard if it makes sense. (For example, perhaps this is a country such as India in which incumbents are generally unpopular; see Linden, 2006.) Try to gather data on potential lurking variables and include them in the analysis.
   4. If a predictor is statistically significant and has the expected sign, then by all means keep it in the model.

These strategies do not completely solve our problems but they help keep us from making mistakes such as discarding important information.

## 1. Predicting the yields of mesquite bushes

The outcome variable is the **total weight** (in grams) of photosynthetic material as derived from actual harvesting of the bush. The input variables are:

* diam1: diameter of the canopy (the leafy area of the bush) in meters, measured along the longer axis of the bush
* diam2: canopy diameter measured along the shorter axis
* canopy.height: height of the canopy
* total.height: total height of the bush
* density: plant unit density (# of primary stems per plant unit)
* group: group of measurements (0 for the first group, 1 for the second group)

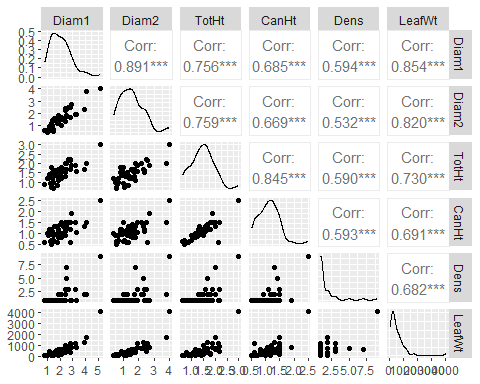
library(ggplot2)  
library(GGally)

## Registered S3 method overwritten by 'GGally':  
## method from   
## +.gg ggplot

mesquite<-read.csv("C:/Users/vinay/OneDrive/Documents/Applied Stats/assignment 3/mesquite.dat", sep="", stringsAsFactors=TRUE)

Observe variables and relationships with ggpairs, except for index variables.

ggpairs(mesquite[,-(1:2)])



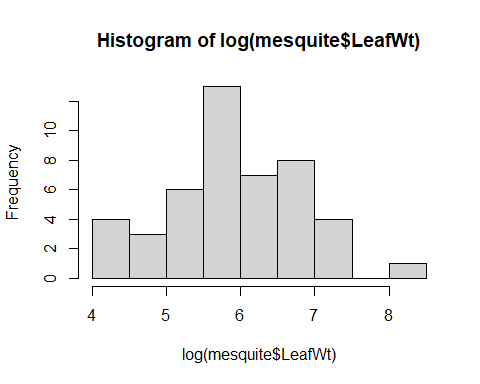
Make a table of the Group variable:

table(mesquite$Group)

##   
## ALS MCD   
## 20 26

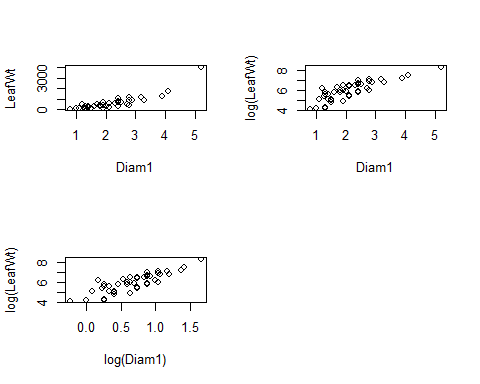
Leaf weight is skewed to the right. Taking log may make it more symmetric. We’ll do that later, but for now, let’s look at the distribution of log(LeafWt):

hist(log(mesquite$LeafWt))



Compare relationships of LeafWt with Diam1

par(mfrow=c(2,2))  
  
plot(LeafWt~Diam1,mesquite)  
plot(log(LeafWt)~Diam1,mesquite)  
plot(log(LeafWt)~log(Diam1),mesquite)

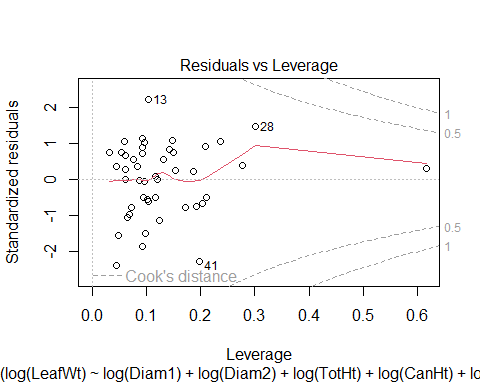
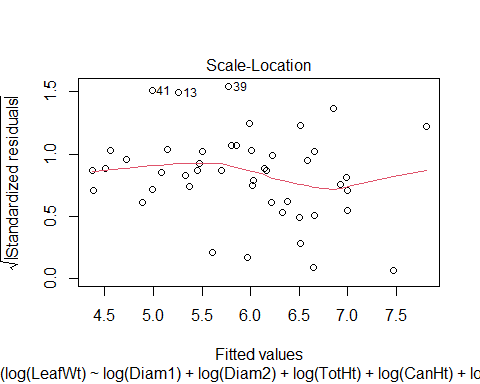
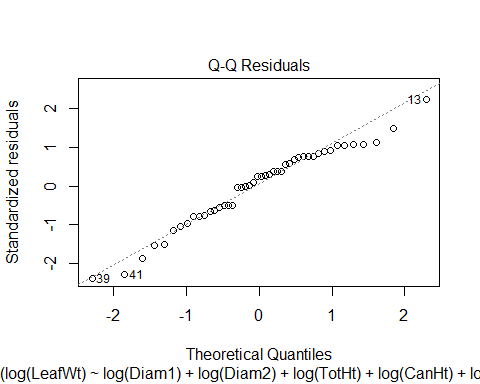
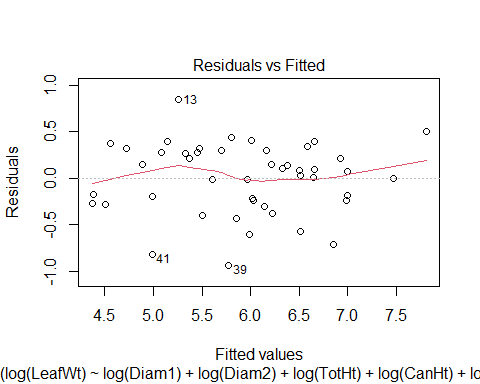


* 1. (5pts) In this situation, taking logs seem to me the relationships more linear. Fit a model where all numeric variables have been transformed with log(). Make a summary of the model and look at the assessment plots.

logLW<-lm(log(LeafWt) ~ log(Diam1) + log(Diam2) + log(TotHt) + log(CanHt) + log(Dens), data=mesquite)  
summary(logLW)

##   
## Call:  
## lm(formula = log(LeafWt) ~ log(Diam1) + log(Diam2) + log(TotHt) +   
## log(CanHt) + log(Dens), data = mesquite)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.93661 -0.23791 0.08061 0.29275 0.84700   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.971382 0.181144 27.444 < 2e-16 \*\*\*  
## log(Diam1) 0.729969 0.331979 2.199 0.03373 \*   
## log(Diam2) 0.786969 0.237002 3.321 0.00193 \*\*   
## log(TotHt) 0.702013 0.372764 1.883 0.06695 .   
## log(CanHt) 0.005042 0.327723 0.015 0.98780   
## log(Dens) -0.107387 0.136888 -0.784 0.43738   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.4021 on 40 degrees of freedom  
## Multiple R-squared: 0.8279, Adjusted R-squared: 0.8063   
## F-statistic: 38.47 on 5 and 40 DF, p-value: 2.939e-14

plot(logLW)

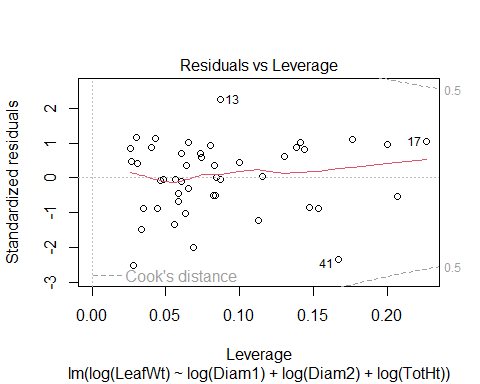
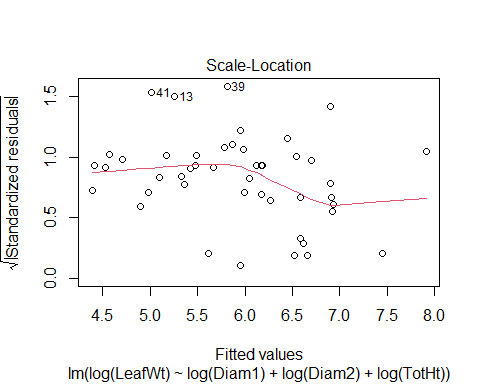
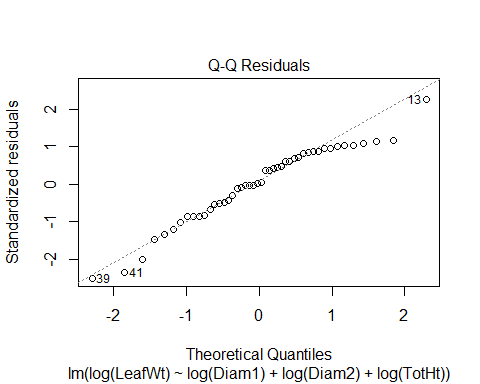
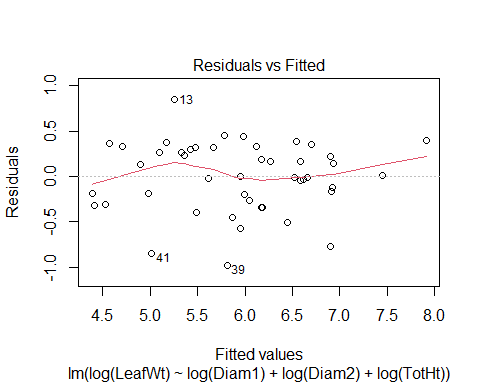


Remove log(CanHt) and log(Dens) and repeat.

logLW2<-lm(log(LeafWt) ~ log(Diam1) + log(Diam2) + log(TotHt), data=mesquite)  
summary(logLW2)

##   
## Call:  
## lm(formula = log(LeafWt) ~ log(Diam1) + log(Diam2) + log(TotHt),   
## data = mesquite)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.97651 -0.24317 0.00991 0.31258 0.84934   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.9994 0.1523 32.820 < 2e-16 \*\*\*  
## log(Diam1) 0.6536 0.3121 2.094 0.04234 \*   
## log(Diam2) 0.8014 0.2319 3.457 0.00127 \*\*   
## log(TotHt) 0.6605 0.2518 2.623 0.01210 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.3955 on 42 degrees of freedom  
## Multiple R-squared: 0.8251, Adjusted R-squared: 0.8127   
## F-statistic: 66.07 on 3 and 42 DF, p-value: 5.995e-16

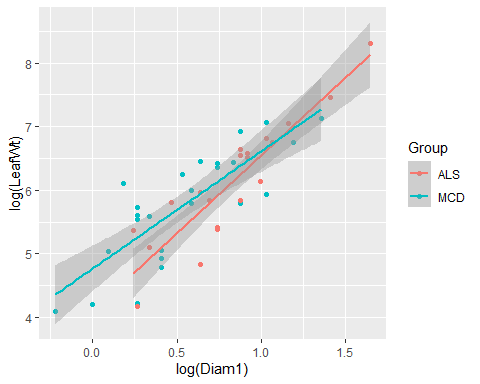
plot(logLW2)



* + 1. Let’s plot by group. The group is being set in the aestetics (aes) of the plot with col=Group.

library(ggplot2)  
  
ggplot(mesquite,aes(x=log(Diam1),y=log(LeafWt),col=Group))+geom\_point()+stat\_smooth(method="lm")

## `geom\_smooth()` using formula = 'y ~ x'

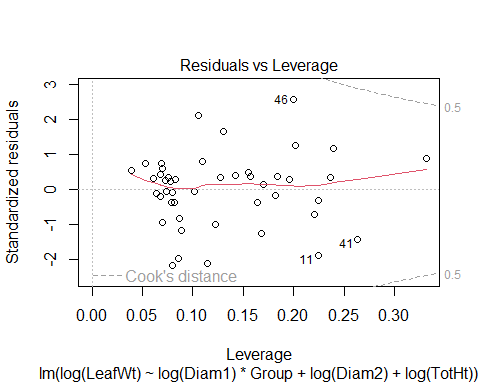
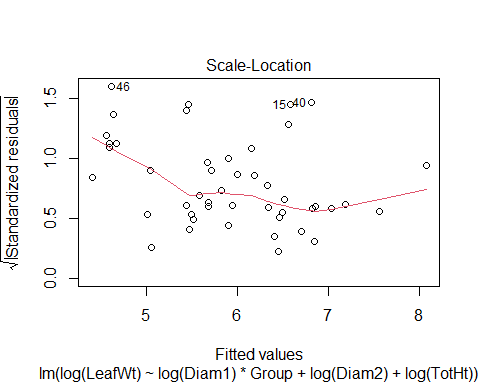
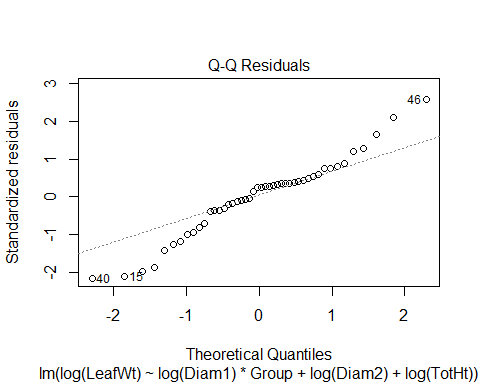
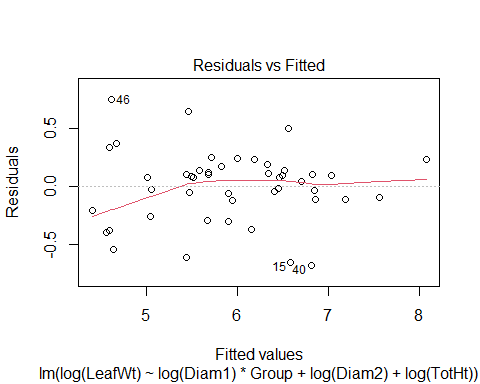


Run a model with interactions between Group and Diam1, and see if there is a significant improvement. Print the summary and look at assessment plots.

logLW3 <- lm(log(LeafWt) ~ log(Diam1)\*Group + log(Diam2) + log(TotHt), data=mesquite)  
summary(logLW3)

##   
## Call:  
## lm(formula = log(LeafWt) ~ log(Diam1) \* Group + log(Diam2) +   
## log(TotHt), data = mesquite)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -0.67414 -0.11508 0.07737 0.14125 0.74765   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 4.4715 0.1950 22.933 < 2e-16 \*\*\*  
## log(Diam1) 0.8309 0.3125 2.658 0.011235 \*   
## GroupMCD 0.8175 0.2265 3.609 0.000846 \*\*\*  
## log(Diam2) 1.0939 0.2004 5.457 2.73e-06 \*\*\*  
## log(TotHt) 0.6490 0.2144 3.027 0.004307 \*\*   
## log(Diam1):GroupMCD -0.4700 0.2790 -1.685 0.099854 .   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 0.325 on 40 degrees of freedom  
## Multiple R-squared: 0.8875, Adjusted R-squared: 0.8734   
## F-statistic: 63.11 on 5 and 40 DF, p-value: < 2.2e-16

plot(logLW3)



1.c) (5) Using model logLW3, write the equation corresponding to each of the groups ALS and MCD. Interpret the effect of Diam1.

case ALS: logLW3=4.4715+0.8309 log(Diam1)+1.0939 log(Diam2)+0.6490 log(TotHt)

case MCD: logLW3=4.4715+0.8309log(Diam1)+1.0939log(Diam2)+0.6490log(TotHt)+0.8175-0.4700

log(Diam1)=4.4715+0.3609 log(Diam1)+1.0939 log(Diam2)+0.6490 log(TotHt)+0.8175

Effect: Case ALS: a one-unit increase in log(Diam1) is associated with an increase in log(LeafWt) by 0.8309 units, holding other variables constant.

Case MCD: a one-unit increase in log(Diam1) is associated with an increase in log(LeafWt) by 0.3609 units, holding other variables constant.

## 2. Earnings vs Height

The folder **earnings** has data from the Work, Family, and Well-Being Survey (Ross, 1990). Pull out the data on earnings, sex, height, and weight.

library(foreign)  
ht<-read.dta("C:/Users/vinay/OneDrive/Documents/Applied Stats/assignment 3/heights.dta", convert.dates = TRUE, convert.factors = TRUE,missing.type = FALSE,convert.underscore = FALSE, warn.missing.labels = TRUE)  
ht

## earn height1 height2 sex race hisp ed yearbn height  
## 1 NA 5 6 2 1 2 12 53 66  
## 2 NA 5 4 1 2 2 12 50 64  
## 3 50000 6 2 1 1 2 16 45 74  
## 4 60000 5 6 2 1 2 16 32 66  
## 5 30000 5 4 2 1 2 16 61 64  
## 6 NA 5 5 2 1 2 17 33 65  
## 7 50000 5 3 2 3 2 16 99 63  
## 8 NA 5 8 2 2 2 18 36 68  
## 9 51000 5 3 2 1 2 17 51 63  
## 10 9000 5 4 2 1 2 15 64 64  
## 11 29000 5 2 2 1 2 12 41 62  
## 12 32000 6 1 1 1 2 17 44 73  
## 13 2000 6 0 1 1 1 15 69 72  
## 14 NA 6 0 1 1 2 99 37 72  
## 15 27000 6 0 1 1 2 12 64 72  
## 16 6530 5 10 1 1 2 16 25 70  
## 17 0 5 3 2 1 2 14 40 63  
## 18 30000 5 8 1 1 2 11 56 68  
## 19 12000 5 8 1 1 2 12 63 68  
## 20 NA 5 11 1 1 2 18 39 71  
## 21 12000 5 5 2 1 2 12 39 65  
## 22 NA 5 6 2 1 2 11 45 66  
## 23 0 5 0 2 1 2 12 63 60  
## 24 NA 5 5 2 1 2 12 49 65  
## 25 NA 5 9 1 1 2 10 39 69  
## 26 22000 5 6 2 1 2 16 55 66  
## 27 NA 5 5 2 1 2 16 61 65  
## 28 NA 5 11 1 1 2 14 68 71  
## 29 17000 5 8 1 1 2 12 32 68  
## 30 40000 5 8 2 1 2 14 61 68  
## 31 44000 5 10 1 1 2 13 46 70  
## 32 0 5 7 2 1 2 9 69 67  
## 33 7000 5 4 2 2 2 12 35 64  
## 34 53000 6 1 1 2 2 13 55 73  
## 35 NA 5 4 2 2 2 12 67 64  
## 36 5000 5 2 2 1 2 13 39 62  
## 37 NA 5 4 2 1 2 12 99 64  
## 38 14000 5 3 2 1 2 14 69 63  
## 39 NA 5 9 1 1 2 14 54 69  
## 40 5500 5 7 1 1 2 14 68 67  
## 41 40000 5 6 2 1 2 12 49 66  
## 42 34000 6 0 1 1 2 12 45 72  
## 43 NA 5 3 2 2 2 12 67 63  
## 44 NA 5 4 2 1 2 12 33 64  
## 45 10000 5 3 2 2 2 12 55 63  
## 46 0 5 8 1 1 2 11 69 68  
## 47 27000 5 4 2 1 2 16 30 64  
## 48 NA 6 1 1 1 2 14 46 73  
## 49 NA 5 7 2 1 2 12 21 67  
## 50 0 5 0 2 1 2 12 46 60  
## 51 50000 6 0 1 1 2 16 52 72  
## 52 0 5 8 2 1 2 12 35 68  
## 53 41000 6 5 1 1 2 16 57 77  
## 54 0 5 4 2 1 2 10 71 64  
## 55 15000 5 4 2 1 2 14 65 64  
## 56 25000 5 4 2 1 2 12 57 64  
## 57 NA 5 3 2 1 2 16 18 63  
## 58 75000 6 0 1 1 2 17 51 72  
## 59 NA 5 8 1 2 2 16 28 68  
## 60 27000 5 8 1 1 2 17 59 68  
## 61 12000 5 4 2 1 2 12 64 64  
## 62 NA 5 10 1 1 2 12 39 70  
## 63 7500 5 1 2 1 2 14 12 61  
## 64 NA 6 4 1 2 2 11 49 76  
## 65 NA 5 5 2 1 2 12 44 65  
## 66 NA 5 4 1 2 2 12 29 64  
## 67 30000 5 7 2 2 2 14 59 67  
## 68 21000 5 5 2 1 2 12 33 65  
## 69 27000 5 4 2 1 2 14 64 64  
## 70 NA 6 1 1 1 2 16 46 73  
## 71 3000 5 7 2 1 2 15 25 67  
## 72 25000 5 5 2 1 2 12 60 65  
## 73 24000 5 5 2 1 2 12 49 65  
## 74 32000 5 7 2 1 2 18 61 67  
## 75 NA NA 98 2 1 2 4 0 NA  
## 76 NA 5 11 1 2 2 12 99 71  
## 77 10000 5 8 2 1 2 17 60 68  
## 78 0 5 10 2 1 2 12 33 70  
## 79 11000 5 0 2 1 1 12 69 60  
## 80 18700 5 5 2 1 2 13 58 65  
## 81 20000 5 2 2 1 2 12 61 62  
## 82 3500 6 0 1 1 2 10 72 72  
## 83 NA 5 6 2 1 2 14 44 66  
## 84 13000 5 7 1 2 2 8 34 67  
## 85 NA 5 9 1 1 2 12 45 69  
## 86 25000 5 10 1 1 2 12 25 70  
## 87 21000 5 10 1 1 2 17 49 70  
## 88 34000 5 8 2 1 2 17 41 68  
## 89 NA 5 6 2 2 2 12 67 66  
## 90 NA 5 1 2 2 2 12 60 61  
## 91 6000 5 0 2 1 2 12 25 60  
## 92 17000 5 11 1 1 2 12 62 71  
## 93 NA 5 10 2 1 2 12 34 70  
## 94 35000 5 11 1 1 2 12 58 71  
## 95 4000 6 1 1 1 2 13 72 73  
## 96 NA 5 4 2 1 2 16 68 64  
## 97 14000 5 8 2 1 2 14 35 68  
## 98 10000 5 6 2 1 2 12 33 66  
## 99 NA 5 9 1 4 2 13 1 69  
## 100 25000 5 9 1 1 2 16 61 69  
## 101 0 5 3 2 1 2 8 27 63  
## 102 NA 5 8 2 1 1 12 61 68  
## 103 NA 5 10 1 1 2 18 30 70  
## 104 16000 5 3 2 1 2 14 63 63  
## 105 0 5 6 2 2 2 13 60 66  
## 106 NA 5 6 2 1 2 12 57 66  
## 107 0 5 4 2 1 2 12 64 64  
## 108 16000 5 2 1 1 1 14 62 62  
## 109 NA 5 6 2 1 2 18 23 66  
## 110 16500 5 4 2 1 2 14 47 64  
## 111 NA 5 8 1 1 2 12 17 68  
## 112 4000 5 4 2 1 2 9 22 64  
## 113 3840 5 7 2 1 2 9 38 67  
## 114 NA 5 0 2 1 2 6 12 60  
## 115 22000 5 11 1 1 2 12 51 71  
## 116 200 5 0 2 1 2 16 37 60  
## 117 26000 5 6 2 1 2 16 63 66  
## 118 2500 5 6 2 1 2 15 69 66  
## 119 17000 5 5 2 1 2 14 51 65  
## 120 NA 5 3 2 1 2 16 55 63  
## 121 8000 5 10 2 1 2 13 68 70  
## 122 NA 5 8 1 1 2 12 59 68  
## 123 0 5 5 2 1 2 13 27 65  
## 124 12000 5 6 2 1 2 13 22 66  
## 125 10000 5 2 2 1 2 12 43 62  
## 126 NA 5 0 2 1 2 8 13 60  
## 127 NA 6 4 1 1 2 16 39 76  
## 128 10000 5 6 2 1 2 15 23 66  
## 129 0 5 4 2 1 2 14 52 64  
## 130 15000 6 0 1 1 2 12 51 72  
## 131 NA 5 6 2 1 2 12 59 66  
## 132 NA 5 2 2 1 2 8 8 62  
## 133 NA 5 6 2 3 2 12 47 66  
## 134 NA 5 9 1 2 2 11 17 69  
## 135 NA 5 8 2 1 2 15 42 68  
## 136 2400 5 7 2 1 1 8 51 67  
## 137 30000 5 8 1 1 1 12 58 68  
## 138 30000 5 10 1 1 2 12 57 70  
## 139 10000 5 2 2 1 2 12 52 62  
## 140 NA 5 10 1 1 2 18 47 70  
## 141 5000 5 3 2 1 2 13 64 63  
## 142 12000 5 6 2 1 2 13 27 66  
## 143 20000 5 10 2 1 2 10 29 70  
## 144 20000 5 8 2 1 2 12 54 68  
## 145 20000 5 10 1 1 2 14 67 70  
## 146 NA 5 5 2 1 2 18 33 65  
## 147 NA 5 8 2 1 2 8 8 68  
## 148 0 5 6 2 1 2 12 31 66  
## 149 NA 5 11 1 1 2 18 14 71  
## 150 1200 5 6 2 1 2 12 70 66  
## 151 NA 5 2 2 1 2 12 21 62  
## 152 700 5 8 2 1 2 16 58 68  
## 153 20000 5 10 1 1 2 16 63 70  
## 154 10000 5 1 2 1 1 12 68 61  
## 155 30000 5 3 2 1 2 12 17 63  
## 156 NA 6 0 1 1 1 8 27 72  
## 157 40000 5 4 2 1 2 14 34 64  
## 158 25000 5 7 1 1 2 12 1 67  
## 159 NA 5 6 2 1 2 18 25 66  
## 160 NA 5 8 2 1 2 14 48 68  
## 161 10000 5 1 2 1 2 17 11 61  
## 162 60000 5 9 2 1 2 18 27 69  
## 163 NA 5 2 2 1 2 12 34 62  
## 164 0 5 4 2 1 2 12 69 64  
## 165 18000 5 8 2 1 2 12 24 68  
## 166 NA 5 0 2 1 2 12 16 60  
## 167 NA 5 11 1 1 2 18 48 71  
## 168 16040 5 4 2 1 2 12 57 64  
## 169 15000 5 7 2 2 2 14 60 67  
## 170 10000 5 9 1 1 2 17 67 69  
## 171 33000 5 7 2 1 2 13 47 67  
## 172 18000 5 8 2 1 2 12 60 68  
## 173 15000 5 3 2 1 2 12 53 63  
## 174 21000 5 11 1 1 2 12 68 71  
## 175 21000 5 4 2 2 2 17 47 64  
## 176 37000 5 8 1 1 2 11 53 68  
## 177 38000 5 8 2 1 2 17 46 68  
## 178 17000 5 6 2 1 1 14 47 66  
## 179 0 5 6 2 1 2 12 61 66  
## 180 0 5 6 2 3 2 16 58 66  
## 181 NA 5 0 2 1 2 16 99 60  
## 182 32000 6 5 1 1 2 16 60 77  
## 183 NA NA NA 1 1 2 12 32 NA  
## 184 27500 5 7 2 1 2 12 32 67  
## 185 NA 5 6 1 1 2 12 14 66  
## 186 16500 5 2 2 1 2 12 46 62  
## 187 NA 5 3 2 1 2 13 99 63  
## 188 0 5 4 2 1 2 17 60 64  
## 189 0 6 0 2 1 2 12 39 72  
## 190 25000 5 7 2 1 2 18 55 67  
## 191 27000 5 1 2 1 2 18 47 61  
## 192 5000 5 4 2 1 2 12 62 64  
## 193 NA 5 10 1 4 2 14 54 70  
## 194 70000 5 2 2 1 2 16 52 62  
## 195 5000 5 3 2 1 2 12 50 63  
## 196 5000 5 8 1 1 2 16 66 68  
## 197 NA 5 9 1 3 2 18 60 69  
## 198 NA 5 4 2 2 2 12 31 64  
## 199 20000 5 4 2 1 2 15 64 64  
## 200 4000 6 0 1 1 2 15 69 72  
## 201 NA 6 0 1 1 2 12 51 72  
## 202 60000 5 4 2 1 2 16 55 64  
## 203 5000 5 1 2 1 2 13 59 61  
## 204 30000 6 2 1 1 2 12 52 74  
## 205 70000 5 10 1 1 2 14 55 70  
## 206 NA 5 4 2 1 2 16 30 64  
## 207 50000 5 11 1 1 2 16 49 71  
## 208 44000 5 3 2 1 2 12 51 63  
## 209 NA NA NA 2 1 2 18 99 NA  
## 210 NA 6 1 1 1 2 18 50 73  
## 211 NA 5 7 1 1 2 17 60 67  
## 212 30000 5 4 2 1 2 14 47 64  
## 213 NA 6 1 1 2 2 14 66 73  
## 214 NA 5 4 2 1 2 16 62 64  
## 215 NA 5 3 2 1 2 15 59 63  
## 216 0 5 2 2 1 2 16 58 62  
## 217 10000 5 2 2 1 2 16 50 62  
## 218 23000 5 10 2 1 2 17 48 70  
## 219 0 5 2 2 1 2 12 51 62  
## 220 45000 5 11 1 1 2 17 28 71  
## 221 15000 5 11 1 1 2 14 59 71  
## 222 NA 5 11 1 1 2 17 57 71  
## 223 4000 5 10 2 1 2 14 19 70  
## 224 17000 5 7 1 1 2 14 59 67  
## 225 30000 5 4 2 1 2 12 58 64  
## 226 27500 5 7 2 1 2 12 60 67  
## 227 5688 5 2 2 1 2 8 21 62  
## 228 18000 5 2 2 1 1 13 34 62  
## 229 NA 5 7 1 1 2 14 54 67  
## 230 NA 5 6 2 1 2 17 58 66  
## 231 NA 5 4 2 1 2 12 27 64  
## 232 43000 5 8 1 2 2 13 46 68  
## 233 32000 5 2 2 2 2 14 46 62  
## 234 NA 5 2 2 2 2 12 70 62  
## 235 0 5 6 2 2 2 5 39 66  
## 236 10000 5 8 2 2 2 18 34 68  
## 237 NA 5 5 2 1 1 12 52 65  
## 238 NA 6 2 1 1 2 12 70 74  
## 239 NA NA NA 2 9 9 16 99 NA  
## 240 60000 6 2 1 1 2 13 45 74  
## 241 NA 5 8 1 1 2 18 24 68  
## 242 NA 5 10 1 1 2 16 60 70  
## 243 NA 5 11 1 1 2 15 67 71  
## 244 21000 5 8 2 4 2 12 40 68  
## 245 2400 5 2 2 1 2 16 68 62  
## 246 NA 5 8 2 1 2 10 40 68  
## 247 NA 5 2 2 2 2 15 48 62  
## 248 1000 5 6 2 1 2 15 62 66  
## 249 27000 5 8 1 1 2 12 63 68  
## 250 6600 5 0 2 1 1 14 62 60  
## 251 NA 5 4 2 2 2 11 39 64  
## 252 16000 5 8 1 1 2 8 47 68  
## 253 90000 6 0 1 1 2 12 64 72  
## 254 8000 5 6 2 1 2 12 48 66  
## 255 20000 5 8 1 1 2 10 58 68  
## 256 15000 5 8 2 1 2 12 72 68  
## 257 12000 5 9 2 1 2 12 30 69  
## 258 NA 5 3 2 1 2 9 23 63  
## 259 24000 5 4 2 1 2 16 44 64  
## 260 20000 5 5 2 1 2 14 51 65  
## 261 NA 4 11 2 1 2 8 8 59  
## 262 19000 5 1 2 1 2 12 44 61  
## 263 NA 5 11 1 1 2 8 37 71  
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## 1869 6000 5 2 2 1 2 12 25 62  
## 1870 5000 5 6 1 1 2 12 15 66  
## 1871 1500 5 6 2 1 1 12 69 66  
## 1872 28000 5 4 2 1 2 18 42 64  
## 1873 9000 5 10 2 1 2 12 55 70  
## 1874 60000 6 2 1 1 2 14 38 74  
## 1875 NA 6 0 1 1 2 16 59 72  
## 1876 1200 5 6 1 1 2 12 71 66  
## 1877 1400 5 2 2 1 1 3 26 62  
## 1878 NA 5 8 2 1 2 16 64 68  
## 1879 7000 5 6 2 1 2 13 47 66  
## 1880 NA 5 6 2 1 2 15 20 66  
## 1881 NA 5 10 1 1 2 12 18 70  
## 1882 21000 5 2 2 1 2 12 59 62  
## 1883 44000 5 9 1 1 2 12 32 69  
## 1884 NA 5 11 1 1 2 12 12 71  
## 1885 29000 5 8 1 2 2 16 54 68  
## 1886 3000 6 0 1 1 1 14 72 72  
## 1887 12000 5 4 1 2 2 13 68 64  
## 1888 0 5 4 2 2 1 16 71 64  
## 1889 0 5 0 2 1 1 9 51 60  
## 1890 20000 6 0 1 1 1 12 62 72  
## 1891 1200 5 2 2 2 2 5 17 62  
## 1892 NA 5 4 2 1 2 12 60 64  
## 1893 37000 6 2 1 1 2 16 65 74  
## 1894 8000 5 6 1 3 2 10 30 66  
## 1895 35000 5 8 1 3 1 16 60 68  
## 1896 NA 5 7 1 1 1 14 67 67  
## 1897 25000 5 2 1 3 2 14 53 62  
## 1898 18000 5 11 2 1 2 10 61 71  
## 1899 30000 5 3 2 2 2 16 54 63  
## 1900 NA 5 6 1 3 2 14 63 66  
## 1901 NA 5 10 1 1 2 8 20 70  
## 1902 20000 5 9 1 1 2 18 21 69  
## 1903 NA 5 3 2 1 2 7 0 63  
## 1904 12000 5 11 1 1 1 6 50 71  
## 1905 0 5 4 2 1 1 12 25 64  
## 1906 10000 5 6 2 1 2 12 22 66  
## 1907 18000 6 0 1 1 2 14 42 72  
## 1908 0 5 2 2 1 1 15 31 62  
## 1909 NA 5 5 2 2 1 12 70 65  
## 1910 NA 5 5 2 2 2 12 47 65  
## 1911 20000 6 0 1 2 2 12 64 72  
## 1912 31000 5 8 2 1 2 16 47 68  
## 1913 NA 5 10 1 2 2 12 34 70  
## 1914 6000 5 4 1 1 1 10 54 64  
## 1915 0 5 4 2 1 2 12 52 64  
## 1916 NA 5 8 1 2 2 12 20 68  
## 1917 12000 5 10 1 1 2 13 50 70  
## 1918 NA 5 3 2 4 2 11 68 63  
## 1919 NA 5 6 2 1 2 13 34 66  
## 1920 13000 5 6 2 1 2 16 57 66  
## 1921 26000 5 7 2 1 2 17 56 67  
## 1922 15000 5 8 2 2 2 11 59 68  
## 1923 30000 5 4 2 1 2 17 62 64  
## 1924 2000 5 5 2 1 2 14 49 65  
## 1925 5000 5 10 1 4 2 13 68 70  
## 1926 53000 5 11 2 1 2 14 64 71  
## 1927 0 5 4 2 1 2 12 54 64  
## 1928 NA 5 10 2 1 2 11 10 70  
## 1929 2000 5 2 2 1 2 13 72 62  
## 1930 25000 5 11 1 1 2 17 61 71  
## 1931 5000 6 2 1 1 2 12 72 74  
## 1932 21000 5 4 2 1 2 13 63 64  
## 1933 NA 5 4 2 1 2 14 71 64  
## 1934 NA 5 11 1 1 2 18 13 71  
## 1935 17000 5 10 2 1 2 15 63 70  
## 1936 NA 6 1 1 1 2 16 68 73  
## 1937 12000 5 4 2 1 2 13 53 64  
## 1938 42000 5 10 1 1 1 14 46 70  
## 1939 21000 6 2 1 1 2 12 57 74  
## 1940 6000 5 3 2 1 1 12 25 63  
## 1941 0 4 11 2 1 1 12 44 59  
## 1942 25000 6 2 1 1 2 14 66 74  
## 1943 3000 5 6 2 1 2 14 71 66  
## 1944 3600 5 5 2 1 2 15 23 65  
## 1945 4000 5 11 1 1 2 12 71 71  
## 1946 20000 5 9 1 1 2 14 32 69  
## 1947 NA 6 0 1 1 2 18 52 72  
## 1948 NA 5 7 2 1 1 16 48 67  
## 1949 NA 5 10 1 1 2 16 39 70  
## 1950 52000 5 0 1 1 2 15 40 60  
## 1951 60000 5 4 2 1 2 12 47 64  
## 1952 15000 5 4 2 1 2 13 49 64  
## 1953 NA 5 3 2 1 2 13 54 63  
## 1954 90000 6 0 1 1 2 16 40 72  
## 1955 NA 5 3 2 1 2 12 52 63  
## 1956 NA 6 0 1 1 1 13 71 72  
## 1957 NA 5 10 2 1 2 12 56 70  
## 1958 NA 5 6 1 1 2 12 14 66  
## 1959 26000 5 1 2 1 2 14 25 61  
## 1960 0 5 2 2 1 1 13 58 62  
## 1961 2000 5 9 1 1 2 12 69 69  
## 1962 16000 5 7 2 1 2 12 29 67  
## 1963 24000 5 5 2 1 1 11 63 65  
## 1964 NA 5 5 2 1 2 12 43 65  
## 1965 15000 5 8 1 1 1 16 62 68  
## 1966 NA 5 11 2 1 2 14 17 71  
## 1967 42000 6 2 1 1 2 17 47 74  
## 1968 0 5 3 2 1 2 15 42 63  
## 1969 NA 5 7 2 1 2 12 18 67  
## 1970 10000 5 5 2 1 2 12 47 65  
## 1971 17000 5 11 1 1 1 13 54 71  
## 1972 30000 5 4 2 1 2 14 56 64  
## 1973 0 5 5 2 1 2 16 68 65  
## 1974 32000 5 9 2 1 2 17 53 69  
## 1975 36000 5 4 2 1 1 17 56 64  
## 1976 10000 6 0 1 1 1 13 70 72  
## 1977 20000 5 3 2 1 2 15 61 63  
## 1978 NA 5 11 1 4 2 10 42 71  
## 1979 24000 5 5 2 1 2 12 61 65  
## 1980 17000 6 0 1 1 2 12 58 72  
## 1981 23000 5 5 2 1 2 14 42 65  
## 1982 25000 5 4 2 1 2 12 57 64  
## 1983 50000 5 11 1 1 2 12 40 71  
## 1984 0 5 3 2 1 2 14 51 63  
## 1985 20000 5 2 2 1 2 12 60 62  
## 1986 30000 5 6 2 1 2 16 57 66  
## 1987 7000 5 4 2 1 2 10 51 64  
## 1988 7000 5 7 1 1 2 10 12 67  
## 1989 30000 5 8 1 1 2 11 58 68  
## 1990 3000 5 6 2 1 2 12 66 66  
## 1991 20000 5 6 2 1 2 14 47 66  
## 1992 40000 5 6 2 1 2 16 31 66  
## 1993 10000 5 7 1 1 2 12 13 67  
## 1994 16000 5 6 1 1 2 12 53 66  
## 1995 11000 5 3 2 1 2 9 39 63  
## 1996 16000 5 8 2 1 2 13 47 68  
## 1997 18000 5 10 1 1 2 12 63 70  
## 1998 NA 5 6 1 1 2 17 23 66  
## 1999 12000 5 3 2 1 2 16 64 63  
## 2000 4000 5 10 1 2 2 14 69 70  
## 2001 60000 6 0 1 1 2 12 45 72  
## 2002 43000 6 3 1 1 2 17 50 75  
## 2003 31000 5 2 2 1 2 14 51 62  
## 2004 50000 5 8 2 1 2 17 51 68  
## 2005 27000 5 8 2 1 2 14 61 68  
## 2006 30000 5 10 1 1 2 17 34 70  
## 2007 12000 6 1 1 2 2 13 69 73  
## 2008 NA 5 6 2 1 2 18 55 66  
## 2009 NA 5 6 1 1 2 18 41 66  
## 2010 0 5 9 2 1 2 16 51 69  
## 2011 20000 5 2 2 1 2 17 60 62  
## 2012 NA 5 3 2 2 2 7 22 63  
## 2013 15000 5 0 2 2 2 12 14 60  
## 2014 25000 5 4 2 3 2 16 53 64  
## 2015 NA 5 8 1 1 1 12 69 68  
## 2016 2000 5 0 2 1 1 6 23 60  
## 2017 NA 5 0 2 1 2 14 22 60  
## 2018 3000 6 1 1 1 1 15 70 73  
## 2019 NA 5 4 2 2 2 16 50 64  
## 2020 110000 5 6 2 3 2 18 42 66  
## 2021 55000 5 9 1 1 2 18 19 69  
## 2022 58000 5 10 1 1 2 18 37 70  
## 2023 10000 5 10 2 1 2 16 54 70  
## 2024 19000 6 0 1 1 2 12 61 72  
## 2025 15000 5 1 2 1 2 18 8 61  
## 2026 8000 5 4 2 1 2 12 57 64  
## 2027 60000 6 0 1 1 2 12 40 72  
## 2028 NA 5 3 2 3 2 14 21 63  
## 2029 6000 5 8 1 1 2 12 63 68

The relationships between the height variables is: height=12\*height1+height2. So just use height for now.

* 1. In R, check the dataset and clean any unusually coded data. Keep only the observation with eranings > 0.

library(dplyr)

##   
## Attaching package: 'dplyr'

## The following objects are masked from 'package:stats':  
##   
## filter, lag

## The following objects are masked from 'package:base':  
##   
## intersect, setdiff, setequal, union

ht<-select(ht,-c("height1","height2"))   
names(ht)

## [1] "earn" "sex" "race" "hisp" "ed" "yearbn" "height"

dim(ht)

## [1] 2029 7

ht<-ht[complete.cases(ht),] # keep only complete cases  
dim(ht)

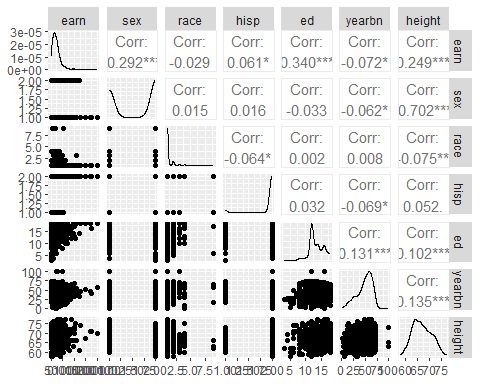
## [1] 1379 7

ht<-subset(ht,earn>0) # keep only positive earnings

1. Do a preliminary data analysis. Consider summary and plots.

ggpairs(ht,cardinalityThreshold=16)

## Warning in warn\_if\_args\_exist(list(...)): Extra arguments:  
## "cardinalityThreshold" are being ignored. If these are meant to be aesthetics,  
## submit them using the 'mapping' variable within ggpairs with ggplot2::aes or  
## ggplot2::aes\_string.



1. Make a summary of all variables:

summary(ht)

## earn sex race hisp   
## Min. : 200 Min. :1.000 Min. :1.000 Min. :1.000   
## 1st Qu.: 10000 1st Qu.:1.000 1st Qu.:1.000 1st Qu.:2.000   
## Median : 20000 Median :2.000 Median :1.000 Median :2.000   
## Mean : 23155 Mean :1.576 Mean :1.167 Mean :1.943   
## 3rd Qu.: 30000 3rd Qu.:2.000 3rd Qu.:1.000 3rd Qu.:2.000   
## Max. :200000 Max. :2.000 Max. :9.000 Max. :2.000   
## ed yearbn height   
## Min. : 3.0 Min. : 1.00 Min. :58.00   
## 1st Qu.:12.0 1st Qu.:39.75 1st Qu.:64.00   
## Median :13.0 Median :52.00 Median :66.00   
## Mean :13.5 Mean :48.87 Mean :66.92   
## 3rd Qu.:16.0 3rd Qu.:61.00 3rd Qu.:70.00   
## Max. :18.0 Max. :99.00 Max. :77.00

1. Which variables are categorical? How many categories do they have? Make tables for each category. Make sure those variables are treated as factors.

str(ht)

## 'data.frame': 1192 obs. of 7 variables:  
## $ earn : num 50000 60000 30000 50000 51000 9000 29000 32000 2000 27000 ...  
## $ sex : int 1 2 2 2 2 2 2 1 1 1 ...  
## $ race : int 1 1 1 3 1 1 1 1 1 1 ...  
## $ hisp : int 2 2 2 2 2 2 2 2 1 2 ...  
## $ ed : num 16 16 16 16 17 15 12 17 15 12 ...  
## $ yearbn: num 45 32 61 99 51 64 41 44 69 64 ...  
## $ height: num 74 66 64 63 63 64 62 73 72 72 ...

ht$sex<-as.factor(ht$sex)  
ht$race<-as.factor(ht$race)  
ht$hisp<-as.factor(ht$hisp)  
ht$ed<-as.factor(ht$ed)  
  
class(ht$sex)

## [1] "factor"

class(ht$race)

## [1] "factor"

class(ht$hisp)

## [1] "factor"

class(ht$ed)

## [1] "factor"

table(ht$sex)

##   
## 1 2   
## 505 687

table(ht$race)

##   
## 1 2 3 4 9   
## 1051 112 15 11 3

table(ht$hisp)

##   
## 1 2   
## 68 1124

table(ht$ed)

##   
## 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18   
## 1 2 3 6 2 21 17 26 29 432 104 176 63 169 66 75

categorical variables are : sex,race,hisp,ed sex has 2 categories race has 5 categories hisp has 2 categories ed has 16 categories

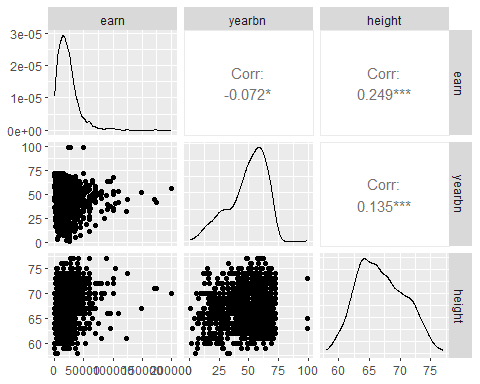
str(ht)

## 'data.frame': 1192 obs. of 7 variables:  
## $ earn : num 50000 60000 30000 50000 51000 9000 29000 32000 2000 27000 ...  
## $ sex : Factor w/ 2 levels "1","2": 1 2 2 2 2 2 2 1 1 1 ...  
## $ race : Factor w/ 5 levels "1","2","3","4",..: 1 1 1 3 1 1 1 1 1 1 ...  
## $ hisp : Factor w/ 2 levels "1","2": 2 2 2 2 2 2 2 2 1 2 ...  
## $ ed : Factor w/ 16 levels "3","4","5","6",..: 14 14 14 14 15 13 10 15 13 10 ...  
## $ yearbn: num 45 32 61 99 51 64 41 44 69 64 ...  
## $ height: num 74 66 64 63 63 64 62 73 72 72 ...

Pay attention to variables that need to be treated as factors. Convert those variables to factor.

1. Plot only numerical variables using ggpairs

numerical\_vars <- sapply(ht, is.numeric)  
numerical\_data <- ht[, numerical\_vars]  
ggpairs(numerical\_data)



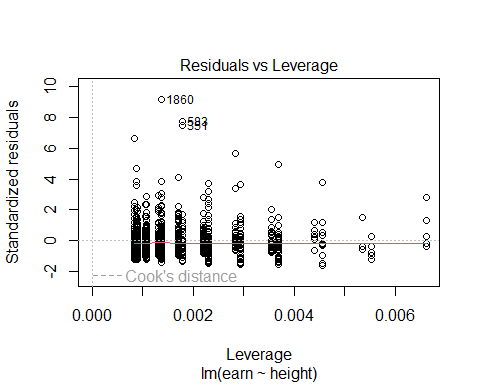
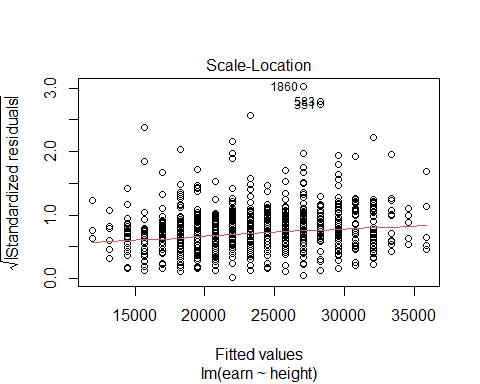
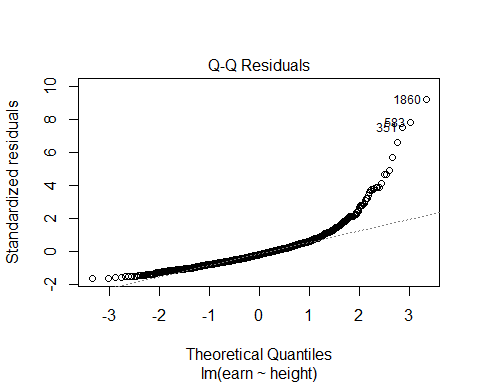
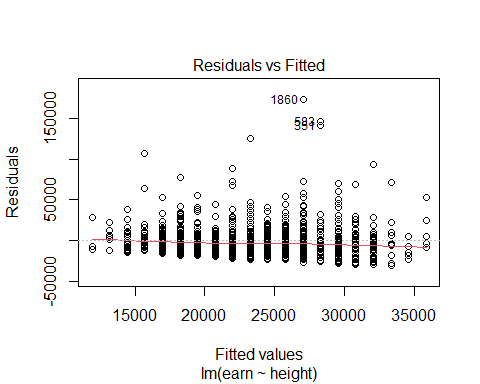
Note: If later on you decide to include the variable yearbn, that a minute to think about what it means and if you should do something to it before using it. The survey was done in 1990. Think about this: a person whose yearbn=0 was born in what year? a person whose yearbn=99 was born in what year?

* + 1. Fit a linear regression model predicting earnings from height and print the model summary.

htmod <- lm(earn ~ height, data=ht)  
summary(htmod)

##   
## Call:  
## lm(formula = earn ~ height, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -30166 -11309 -3428 6527 172953   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) -61316.3 9525.2 -6.437 1.76e-10 \*\*\*  
## height 1262.3 142.1 8.883 < 2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 18870 on 1190 degrees of freedom  
## Multiple R-squared: 0.06218, Adjusted R-squared: 0.06139   
## F-statistic: 78.9 on 1 and 1190 DF, p-value: < 2.2e-16

plot(htmod)



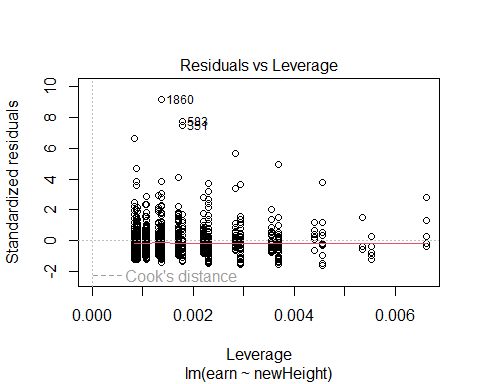
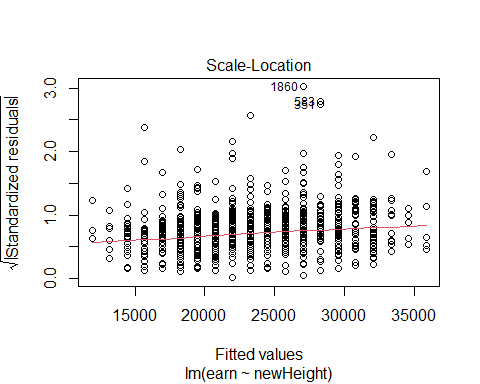
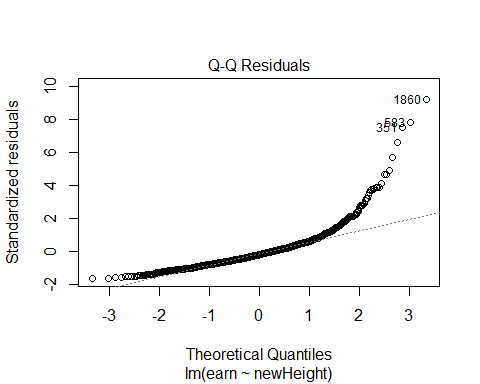
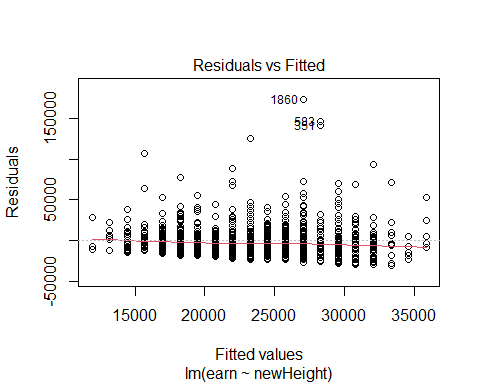
* + 1. What transformation should you perform in order to interpret the intercept from this model as average earnings for people with average height?

Transform the variable height and fit a new model of earn on the transformed variable. Print the summary of the model.

ht$newHeight <- ht$height-mean(ht$height)  
modHeightA <- lm(earn~newHeight,ht)  
summary(modHeightA)

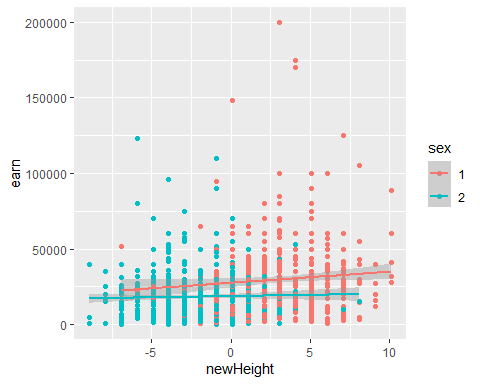
##   
## Call:  
## lm(formula = earn ~ newHeight, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -30166 -11309 -3428 6527 172953   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 23154.8 546.4 42.376 <2e-16 \*\*\*  
## newHeight 1262.3 142.1 8.883 <2e-16 \*\*\*  
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 18870 on 1190 degrees of freedom  
## Multiple R-squared: 0.06218, Adjusted R-squared: 0.06139   
## F-statistic: 78.9 on 1 and 1190 DF, p-value: < 2.2e-16

plot(modHeightA)



ggplot(ht,aes(x=newHeight,y=earn,col=sex))+geom\_point()+  
geom\_smooth(method = lm)

## `geom\_smooth()` using formula = 'y ~ x'



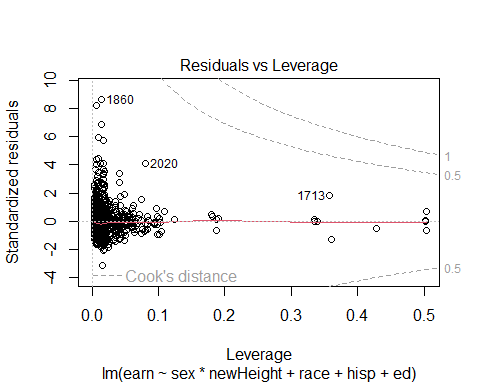
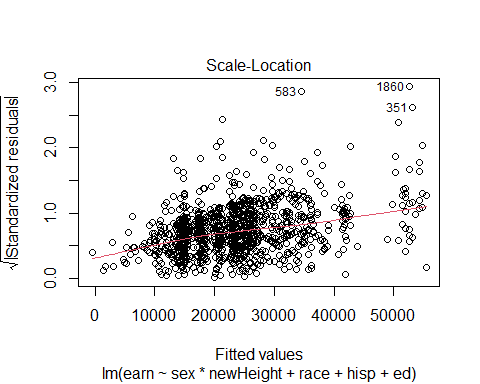
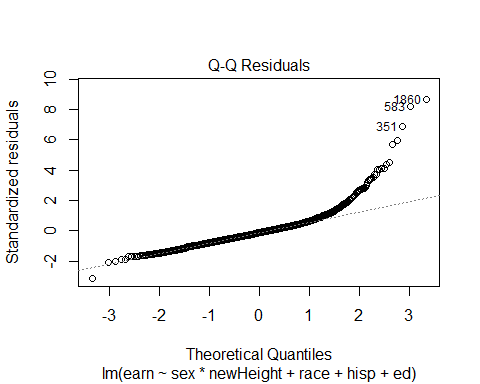
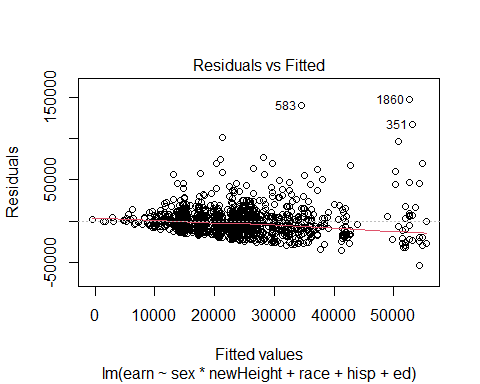
* + 1. Fit some regression models with the goal of predicting earnings from some combination of sex, height, race and education. Be sure to try various transformations and interactions that might make sense. Choose your preferred model and justify. Use ggplot() with color equal the categorical variable on which you are considering interactions to guide your analysis.

modHeightB<-lm(earn~sex\*newHeight+race+hisp+ed,data=ht)  
summary(modHeightB)

##   
## Call:  
## lm(formula = earn ~ sex \* newHeight + race + hisp + ed, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -53308 -9734 -1991 5997 147423   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 9860.5 17255.6 0.571 0.5678   
## sex2 -9410.1 1451.0 -6.485 1.3e-10 \*\*\*  
## newHeight 576.7 265.0 2.176 0.0297 \*   
## race2 -2720.3 1724.6 -1.577 0.1150   
## race3 1257.7 4580.0 0.275 0.7837   
## race4 -7745.4 5230.8 -1.481 0.1389   
## race9 7244.4 10412.1 0.696 0.4867   
## hisp2 4731.1 2201.7 2.149 0.0319 \*   
## ed4 -3975.8 21191.5 -0.188 0.8512   
## ed5 -1710.5 19988.3 -0.086 0.9318   
## ed6 -2308.8 18739.9 -0.123 0.9020   
## ed7 -3451.5 21224.8 -0.163 0.8708   
## ed8 2553.5 17721.7 0.144 0.8855   
## ed9 4154.9 17825.7 0.233 0.8157   
## ed10 7873.5 17670.9 0.446 0.6560   
## ed11 10083.0 17623.5 0.572 0.5673   
## ed12 9000.0 17353.1 0.519 0.6041   
## ed13 12099.7 17409.7 0.695 0.4872   
## ed14 15021.2 17381.4 0.864 0.3877   
## ed15 11936.5 17458.0 0.684 0.4943   
## ed16 17614.8 17387.0 1.013 0.3112   
## ed17 19661.0 17468.8 1.125 0.2606   
## ed18 36207.6 17458.5 2.074 0.0383 \*   
## sex2:newHeight -769.9 368.0 -2.092 0.0367 \*   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 17190 on 1168 degrees of freedom  
## Multiple R-squared: 0.2355, Adjusted R-squared: 0.2205   
## F-statistic: 15.65 on 23 and 1168 DF, p-value: < 2.2e-16

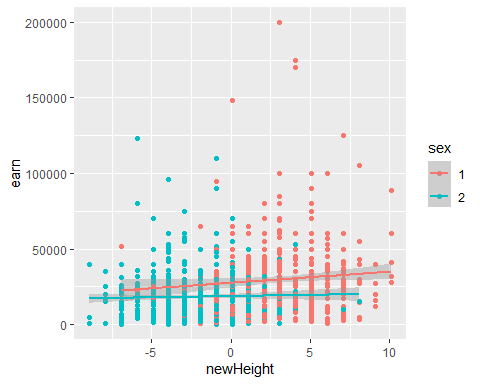
plot(modHeightB)

## Warning: not plotting observations with leverage one:  
## 1091



ggplot(ht,aes(x=newHeight,y=earn,col=sex))+geom\_point()+geom\_smooth(method = lm)

## `geom\_smooth()` using formula = 'y ~ x'

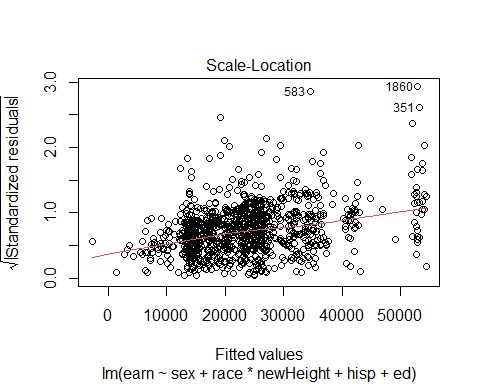
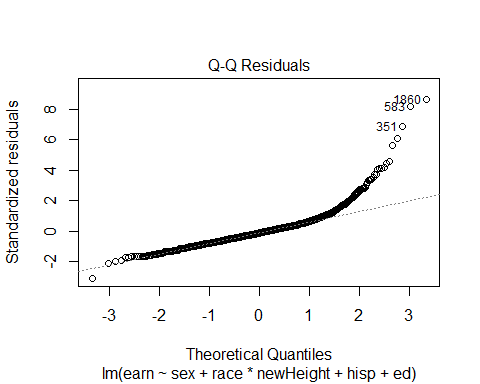
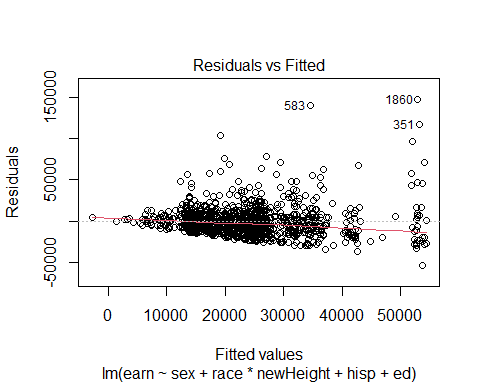


modHeightC<-lm(earn~sex+race\*newHeight+hisp+ed,data=ht)  
summary(modHeightC)

##   
## Call:  
## lm(formula = earn ~ sex + race \* newHeight + hisp + ed, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -52836 -9800 -2133 5900 147038   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 12585.93 17231.80 0.730 0.4653   
## sex2 -9754.18 1442.49 -6.762 2.15e-11 \*\*\*  
## race2 -3004.45 1730.38 -1.736 0.0828 .   
## race3 828.29 5848.98 0.142 0.8874   
## race4 -7647.26 5400.63 -1.416 0.1570   
## race9 -13176.22 21932.84 -0.601 0.5481   
## newHeight 291.19 194.06 1.501 0.1338   
## hisp2 4435.97 2217.26 2.001 0.0457 \*   
## ed4 -5714.59 21191.90 -0.270 0.7875   
## ed5 -1978.70 20002.93 -0.099 0.9212   
## ed6 -3634.10 18823.11 -0.193 0.8469   
## ed7 -2119.30 21242.01 -0.100 0.9205   
## ed8 1397.92 17726.58 0.079 0.9372   
## ed9 3992.81 17832.47 0.224 0.8229   
## ed10 6254.51 17675.95 0.354 0.7235   
## ed11 9114.08 17626.57 0.517 0.6052   
## ed12 7749.54 17357.69 0.446 0.6553   
## ed13 10946.51 17411.81 0.629 0.5297   
## ed14 13694.98 17384.52 0.788 0.4310   
## ed15 10871.62 17463.62 0.623 0.5337   
## ed16 16363.26 17390.77 0.941 0.3469   
## ed17 18324.40 17474.16 1.049 0.2946   
## ed18 35042.56 17463.03 2.007 0.0450 \*   
## race2:newHeight -992.44 438.05 -2.266 0.0237 \*   
## race3:newHeight 55.69 1734.38 0.032 0.9744   
## race4:newHeight -261.71 1348.40 -0.194 0.8461   
## race9:newHeight -6367.03 6059.81 -1.051 0.2936   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 17200 on 1165 degrees of freedom  
## Multiple R-squared: 0.2368, Adjusted R-squared: 0.2198   
## F-statistic: 13.9 on 26 and 1165 DF, p-value: < 2.2e-16

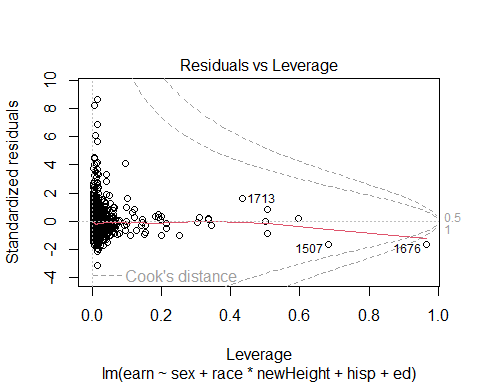
plot(modHeightC)

## Warning: not plotting observations with leverage one:  
## 1091



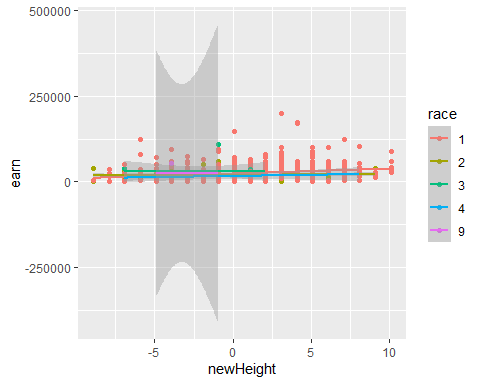
## Warning in sqrt(crit \* p \* (1 - hh)/hh): NaNs produced

## Warning in sqrt(crit \* p \* (1 - hh)/hh): NaNs produced



ggplot(ht,aes(x=newHeight,y=earn,col=race))+geom\_point()+  
geom\_smooth(method = lm)

## `geom\_smooth()` using formula = 'y ~ x'

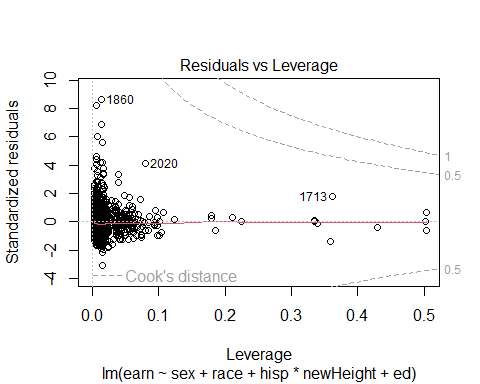
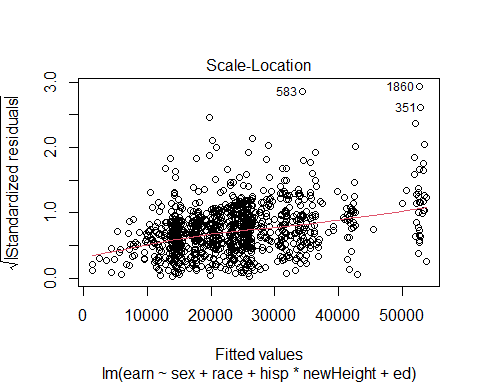
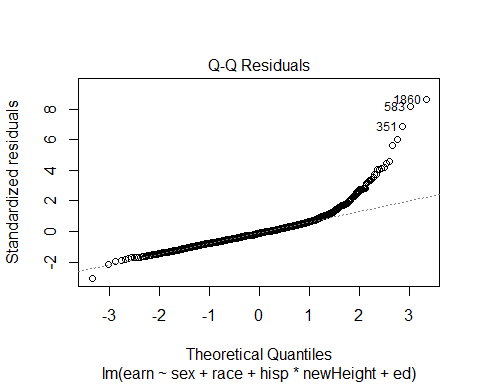
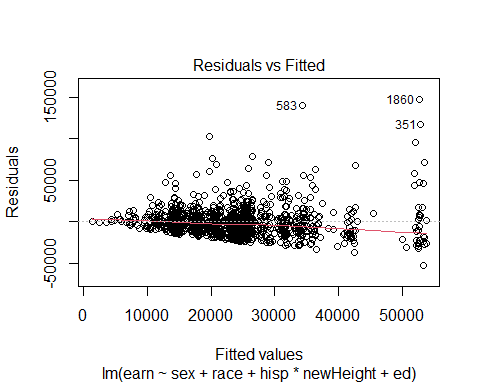


modHeightD<-lm(earn~sex+race+hisp\*newHeight+ed,data=ht)  
summary(modHeightD)

##   
## Call:  
## lm(formula = earn ~ sex + race + hisp \* newHeight + ed, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -52374 -9988 -1916 6014 147266   
##   
## Coefficients:  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 9730.7 17449.4 0.558 0.5772   
## sex2 -9789.2 1442.1 -6.788 1.8e-11 \*\*\*  
## race2 -2716.9 1727.4 -1.573 0.1160   
## race3 608.1 4574.0 0.133 0.8943   
## race4 -7479.9 5237.8 -1.428 0.1535   
## race9 6663.9 10437.9 0.638 0.5233   
## hisp2 5065.1 2240.5 2.261 0.0240 \*   
## newHeight -296.6 569.1 -0.521 0.6023   
## ed4 -3425.5 21328.9 -0.161 0.8724   
## ed5 1274.8 20166.7 0.063 0.9496   
## ed6 -697.7 18892.4 -0.037 0.9705   
## ed7 -1628.4 21355.5 -0.076 0.9392   
## ed8 3672.4 17884.8 0.205 0.8373   
## ed9 5417.6 17983.4 0.301 0.7633   
## ed10 8635.9 17822.8 0.485 0.6281   
## ed11 11072.4 17778.9 0.623 0.5335   
## ed12 10030.6 17512.1 0.573 0.5669   
## ed13 13169.3 17589.8 0.749 0.4542   
## ed14 16011.3 17547.8 0.912 0.3617   
## ed15 13253.9 17643.0 0.751 0.4527   
## ed16 18648.7 17550.4 1.063 0.2882   
## ed17 20529.2 17620.4 1.165 0.2442   
## ed18 37280.8 17621.0 2.116 0.0346 \*   
## hisp2:newHeight 510.0 570.3 0.894 0.3714   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 17220 on 1168 degrees of freedom  
## Multiple R-squared: 0.2332, Adjusted R-squared: 0.2181   
## F-statistic: 15.44 on 23 and 1168 DF, p-value: < 2.2e-16

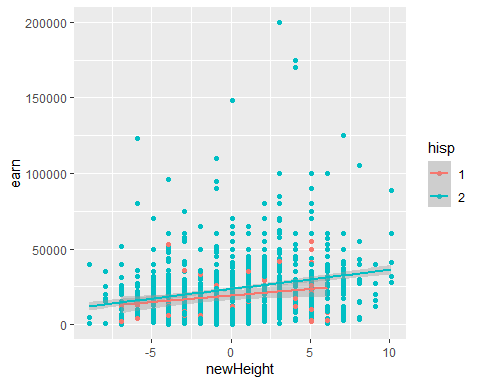
plot(modHeightD)

## Warning: not plotting observations with leverage one:  
## 1091



ggplot(ht,aes(x=newHeight,y=earn,col=hisp))+geom\_point()+  
geom\_smooth(method = lm)

## `geom\_smooth()` using formula = 'y ~ x'



modHeightE<-lm(earn~sex+race+hisp+ed\*newHeight,data=ht)  
sd(ht$ed18)

## [1] NA

sd(ht$newHeight)

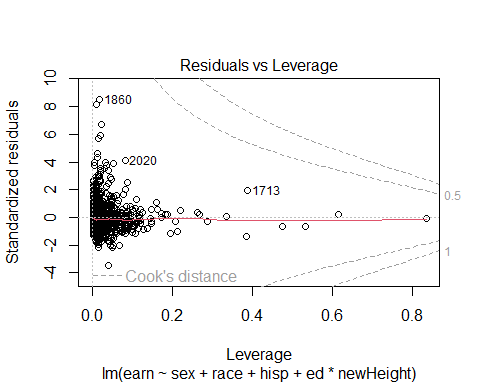
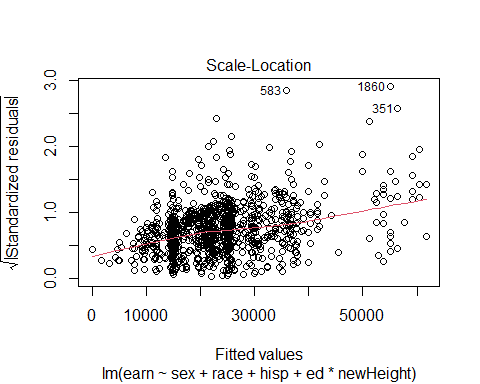
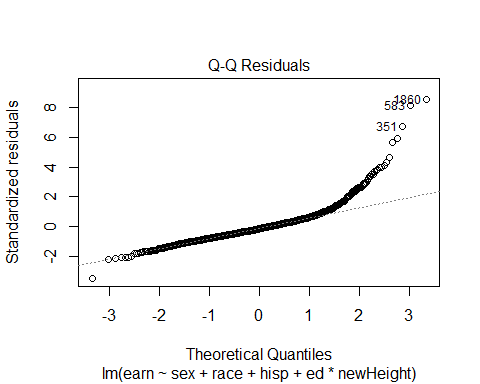
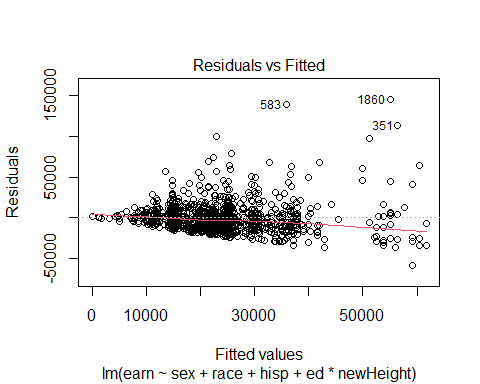
## [1] 3.846638

summary(modHeightE)

##   
## Call:  
## lm(formula = earn ~ sex + race + hisp + ed \* newHeight, data = ht)  
##   
## Residuals:  
## Min 1Q Median 3Q Max   
## -58086 -9707 -1973 5823 144861   
##   
## Coefficients: (1 not defined because of singularities)  
## Estimate Std. Error t value Pr(>|t|)   
## (Intercept) 17456.4 17423.1 1.002 0.3166   
## sex2 -9586.2 1447.0 -6.625 5.32e-11 \*\*\*  
## race2 -3031.2 1747.6 -1.734 0.0831 .   
## race3 1764.9 4604.6 0.383 0.7016   
## race4 -7521.9 5244.5 -1.434 0.1518   
## race9 7055.8 10876.6 0.649 0.5167   
## hisp2 4835.1 2223.5 2.175 0.0299 \*   
## ed4 -11134.4 21871.5 -0.509 0.6108   
## ed5 -8259.7 46782.5 -0.177 0.8599   
## ed6 -8047.5 18957.8 -0.424 0.6713   
## ed7 20197.5 50221.2 0.402 0.6876   
## ed8 -4625.9 17965.1 -0.257 0.7968   
## ed9 -2238.7 18026.4 -0.124 0.9012   
## ed10 847.8 17873.8 0.047 0.9622   
## ed11 3446.3 17826.4 0.193 0.8467   
## ed12 2467.9 17558.0 0.141 0.8882   
## ed13 5885.7 17614.1 0.334 0.7383   
## ed14 8490.0 17583.0 0.483 0.6293   
## ed15 5085.4 17664.6 0.288 0.7735   
## ed16 10769.1 17590.2 0.612 0.5405   
## ed17 12893.1 17671.0 0.730 0.4658   
## ed18 28790.0 17729.5 1.624 0.1047   
## newHeight 1315.9 567.0 2.321 0.0205 \*   
## ed4:newHeight -911.3 8134.0 -0.112 0.9108   
## ed5:newHeight -1383.1 6123.6 -0.226 0.8213   
## ed6:newHeight -1333.5 1569.9 -0.849 0.3958   
## ed7:newHeight -6326.3 8149.9 -0.776 0.4378   
## ed8:newHeight -1732.8 1107.4 -1.565 0.1179   
## ed9:newHeight -623.7 1136.7 -0.549 0.5833   
## ed10:newHeight -2459.2 1125.0 -2.186 0.0290 \*   
## ed11:newHeight -1577.8 972.7 -1.622 0.1050   
## ed12:newHeight -1201.0 587.0 -2.046 0.0410 \*   
## ed13:newHeight -414.5 715.6 -0.579 0.5626   
## ed14:newHeight -1597.1 642.9 -2.484 0.0131 \*   
## ed15:newHeight -1926.5 771.2 -2.498 0.0126 \*   
## ed16:newHeight -626.3 648.7 -0.966 0.3345   
## ed17:newHeight -983.1 799.9 -1.229 0.2193   
## ed18:newHeight NA NA NA NA   
## ---  
## Signif. codes: 0 '\*\*\*' 0.001 '\*\*' 0.01 '\*' 0.05 '.' 0.1 ' ' 1  
##   
## Residual standard error: 17200 on 1155 degrees of freedom  
## Multiple R-squared: 0.2432, Adjusted R-squared: 0.2196   
## F-statistic: 10.31 on 36 and 1155 DF, p-value: < 2.2e-16

plot(modHeightE)

## Warning: not plotting observations with leverage one:  
## 702, 731, 958, 1060, 1091



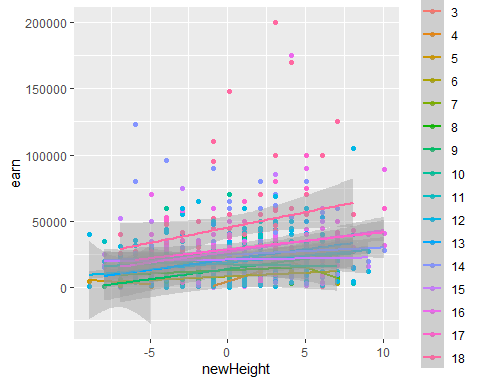
ggplot(ht,aes(x=newHeight,y=earn,col=ed))+geom\_point()+  
geom\_smooth(method = lm)

## `geom\_smooth()` using formula = 'y ~ x'

## Warning in qt((1 - level)/2, df): NaNs produced

## Warning in qt((1 - level)/2, df): NaNs produced

## Warning in max(ids, na.rm = TRUE): no non-missing arguments to max; returning  
## -Inf  
  
## Warning in max(ids, na.rm = TRUE): no non-missing arguments to max; returning  
## -Inf



* + 1. Interpret all model coefficients.

from modHeightB: case sex1: earn=9860.5+576.7 newHeight case sex2: earn=9860.5+576.7 newHeight-9410.1-769.9 newHeight =450.4-193.2 newHeight case sex1:Increase in one unit of newHeight result in increase of 576.7 units of earnings. case sex2:Increase in one unit of newHeight result in decrease of 193.2 units of earnings.

from modHeightC:case race4: earn=12585.93-7647.26+291.19 newHeight-261.71 newHeight =4938.67+29.48 newHeight Increase in one unit of newHeight result in increase of 29.48 units of earnings.

from modHeightD:case hisp2: earn=9730.7+5065.1-296.6 newHeight+510.0 newHeight =14795.8+213.4 newHeight Increase in one unit of newHeight result in increase of 213.4 units of earnings.

from modHeightE:case ed9: earn=17456.4-2238.7+1315.9 newHeight-623.7 newHeight =15217.7+692.2 newHeight Increase in one unit of newHeight result in increase of 692.2 units of earnings.

In modHeightB:

For sex1, earnings increase by 576.7 units for each one-unit increase in newHeight. For sex2, earnings decrease by 193.2 units for each one-unit increase in newHeight. In modHeightC:

For race4, each one-unit increase in newHeight leads to a 29.48 unit increase in earnings. In modHeightD:

For hisp2, an increase of one unit in newHeight results in an earnings increase of 213.4 units. In modHeightE:

For ed9, earnings increase by 692.2 units for every one-unit increase in newHeight.

ed18:newHeight = 28790.0 + 1.624 \* newHeight

So, the equation for “ed18” would be:

ed18 = 28790.0 + 1.624 \* newHeight

* + 1. Examine the outliers and points of influence in your model with influencePlot()

library(car)

## Loading required package: carData

##   
## Attaching package: 'car'

## The following object is masked from 'package:dplyr':  
##   
## recode

influencePlot(modHeightE, id.method = "identify", main = "Influence Plot")

## Warning in plot.window(...): "id.method" is not a graphical parameter

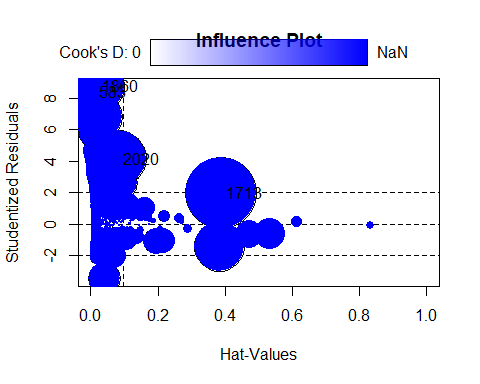
## Warning in plot.xy(xy, type, ...): "id.method" is not a graphical parameter

## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not  
## a graphical parameter  
  
## Warning in axis(side = side, at = at, labels = labels, ...): "id.method" is not  
## a graphical parameter

## Warning in box(...): "id.method" is not a graphical parameter

## Warning in title(...): "id.method" is not a graphical parameter

## Warning in plot.xy(xy.coords(x, y), type = type, ...): "id.method" is not a  
## graphical parameter



## StudRes Hat CookD  
## 583 8.375121 0.01164069 0.02106659  
## 1190 NaN 1.00000000 NaN  
## 1238 NaN 1.00000000 NaN  
## 1713 1.971823 0.38881370 0.06668336  
## 1860 8.778795 0.01920144 0.03825800  
## 2020 4.151855 0.08218496 0.04113927

Write a sentence about your findings.

The data points at 583, 1713, 1860, and 2020 exhibit a significant Cook’s distance, indicating their strong influence on the model. This influence, in turn, affects the estimation of the model’s coefficients. Therefore, it is advisable to conduct further analysis on these specific data points to improve the accuracy of the coefficient estimates.