STAT 401A - Statistical Methods for Research Workers

Model refinement analysis - Ames housing prices

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Objective

Determine the fair market value of a house in Ames with asking price of $240,000 with the following details:

- 2-story on 9201 ft^2 land
- 4 bedroom
- 2 bathroom
- 2 car attached garage
- built in 1975
- 2199 ft^2 above grade plus
- basement: 780 ft^2 (75% finished) with additional bath

based on houses sold in Ames from June 2010 to August 2011.

What does fair market value mean?

- What would people pay on average?
- What would we predict the next person would pay?

Multiple regression

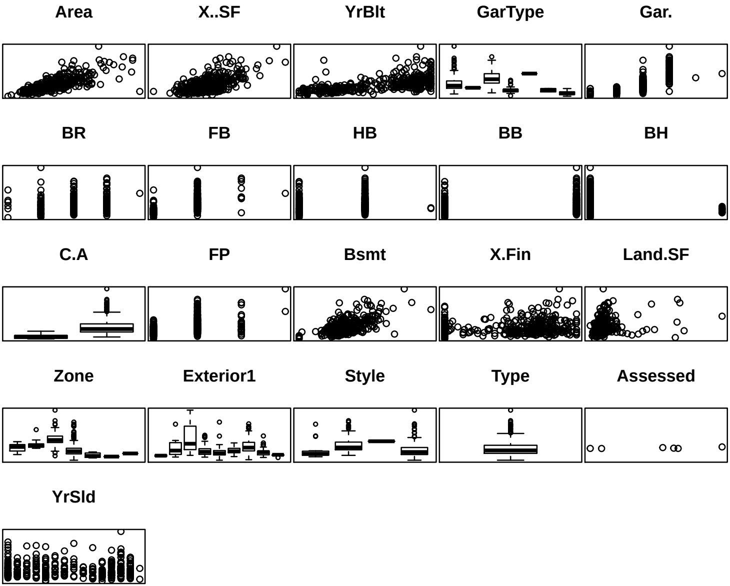
Decisions to make before performing analysis (you can change your mind)

- Data
  - June 2010 to August 2011
  - 2-story vs 1.5-story vs 1-story
- Response
  - Price (log?)
- Explanatory variables
  - continuous vs categorical, e.g. # of bathrooms
  - transformations (log)
  - higher order (squared terms)
  - interactions

Explanatory variables

- Year built
- Year/month sold
- Area of
  - Land
  - Above grade living space
  - Basement living space
- Number of
  - Bedrooms
  - Bathrooms above grade
  - Half bathrooms above grade
  - Bathrooms in basement
  - Half bathrooms in basement
  - Fireplaces
- Garage
  - size: number of cars
  - type: (attached, detached, etc)
- Exterior type: (VinylSd, HdBoard, etc)
- Number of levels
- Percent of basement that is finished

```
[1] 363  27
     Price             GarType      C.A           Style        Exterior1
 Min.   : 62000   Attachd:271   No :  6   1.5 Fin: 16   VinylSd:163
 1st Qu.:144250   Basment:  3   Yes:357   2-Story:123   HdBoard: 66
 Median :180000   BuiltIn: 31             2.5 Unf:  1   Wd Sdng: 36
 Mean   :204772   Detachd: 47             1-Story:223   MetalSd: 35
 3rd Qu.:241750   2 Types:  1                           Plywood: 28
 Max.   :665000   No Data:  2                           CemntBd: 18
                  None   :  8                           (Other): 17
AsbShng BrkFace CemntBd HdBoard MetalSd Plywood VinylSd Wd Sdng WdShing
      2       8      18      66      35      28     163      36       7
```


Area
X..SF
YrBlt
GarType
Gar.
BR
FB
HB
BB
BH
C.A
FP
Bsmt
X.Fin
Land.SF
Zone
Exterior1
Style
Type
Assessed
YrSld

Exploratory analysis

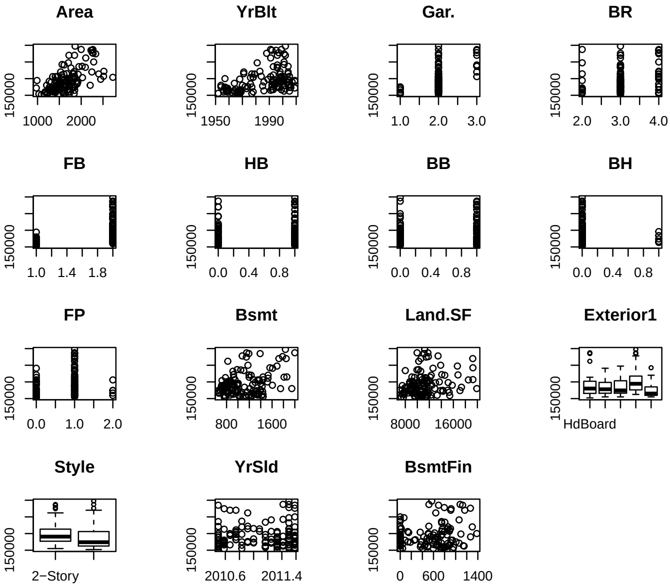
Adjustments made:

- Slimmed data set to include only the following
  - Zoned residential low density
  - Sell price \$150-\$300k
  - Has central air
  - 1-story or 2-story (no 1.5 or 2.5 story)
  - Exterior not AsbShng, BrkFace, WdShing
- Created new variables:
  - Date sold (Year+Month/12)
  - Basement finished area
  - Basement unfinished area
- Variables eliminated
  - % of basement finished

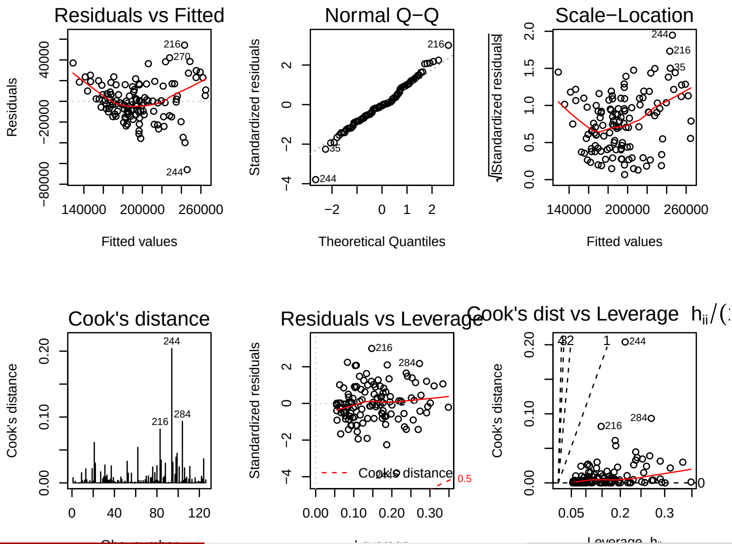
Fit initial model with all explanatory variables, but no interaction

Slimmed data set

```
[1] 126  16
     Price               Area           YrBlt           Gar.              BR              FB              HB
 Min.   :152000   Min.   : 972   Min.   :1952   Min.   :1.000   Min.   :2.000   Min.   :1.000   Min.   :0.0000
 1st Qu.:169000   1st Qu.:1410   1st Qu.:1969   1st Qu.:2.000   1st Qu.:3.000   1st Qu.:2.000   1st Qu.:0.0000
 Median :185500   Median :1613   Median :1992   Median :2.000   Median :3.000   Median :2.000   Median :1.0000
 Mean   :194279   Mean   :1659   Mean   :1986   Mean   :1.984   Mean   :3.111   Mean   :1.802   Mean   :0.6111
 3rd Qu.:206800   3rd Qu.:1846   3rd Qu.:1999   3rd Qu.:2.000   3rd Qu.:3.000   3rd Qu.:2.000   3rd Qu.:1.0000
 Max.   :297500   Max.   :2726   Max.   :2009   Max.   :3.000   Max.   :4.000   Max.   :2.000   Max.   :1.0000
       BB                BH                FP              Bsmt          Land.SF          Exterior1      Style
 Min.   :0.0000   Min.   :0.00000   Min.   :0.0000   Min.   : 654   Min.   : 7153   HdBoard:31   2-Story:64
 1st Qu.:0.0000   1st Qu.:0.00000   1st Qu.:0.0000   1st Qu.: 832   1st Qu.: 9309   MetalSd:10   1-Story:62
 Median :0.0000   Median :0.00000   Median :1.0000   Median :1045   Median :10785   Plywood:15
 Mean   :0.4286   Mean   :0.03968   Mean   :0.7143   Mean   :1117   Mean   :11233   VinylSd:59
 3rd Qu.:1.0000   3rd Qu.:0.00000   3rd Qu.:1.0000   3rd Qu.:1349   3rd Qu.:12114   Wd Sdng:11
 Max.   :1.0000   Max.   :1.00000   Max.   :2.0000   Max.   :2000   Max.   :19900
     YrSld          BsmtFin
 Min.   :2010   Min.   :   0.0
 1st Qu.:2011   1st Qu.:   0.0
 Median :2011   Median : 583.2
 Mean   :2011   Mean   : 508.2
 3rd Qu.:2012   3rd Qu.: 808.2
 Max.   :2012   Max.   :1381.4
```


Area
150000
1000
2000
YrBlt
150000
1950
1990
Gar.
150000
1.0
2.0
3.0
BR
150000
2.0
3.0
4.0
FB
150000
1.0
1.4
1.8
HB
150000
0.0
0.4
0.8
BB
150000
0.0
0.4
0.8
BH
150000
0.0
0.4
0.8
FP
150000
0.0
1.0
2.0
Bsmt
150000
800
1600
Land.SF
150000
8000
16000
Exterior1
150000
HdBoard
Style
150000
2−Story
YrSld
150000
2010.6
2011.4
BsmtFin
150000
0
600
1400

```
mod = lm(Price~., slim)
par(mfrow=c(2,3))
plot(mod,1:6, ask=F)
```



Response and outliers

Comments from plots:

- There is some evidence that increased price leads to increased residuals, so consider logarithm of Price as the response.
- Some observations were flagged as important, but none are exerting an undo influence on the regression (Cook's distance less than 0.20).
- There is a concern that there are outlying observations and therefore heavier tails.

Training-testing data sets

For example,

1. Randomly split your observations into two sets:
   - training
   - testing
2. Use the training data set to find model(s), e.g.
   - use a model selection procedure to find a model and
   - estimate the parameters in that model.
3. Use the testing data set to evaluate the model(s), e.g. calculate mean square prediction in the testing data, i.e.

$$MSPE = \frac{1}{n'} \sum_{i=1}^{n'} (P_i - \hat{P}_i)^2$$

where

- P_i is the actual sale price for house i in the testing data set and
- $\hat{P}_i$ is the predicted sale price from a particular model.

Candidate models

Use all explanatory variables from earlier and allow the following models combinations:

- Response: Price and log(Price)
- Interactions: Yes and No
- Selection criterion: AIC and BIC

For a particular combination,

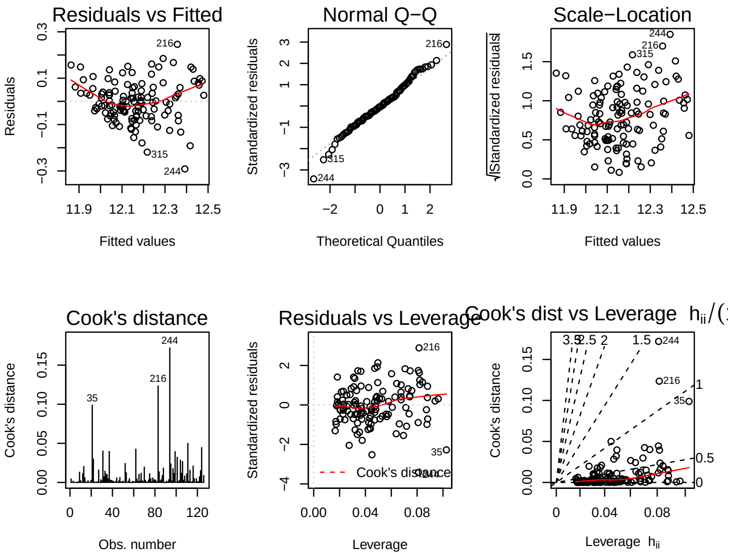
1. Initialize model to have all main effects.
2. Use stepwise selection to select a model.
3. Calculate the model's MSPE

Choose the model that has the lowest mean square error amongst all these models.

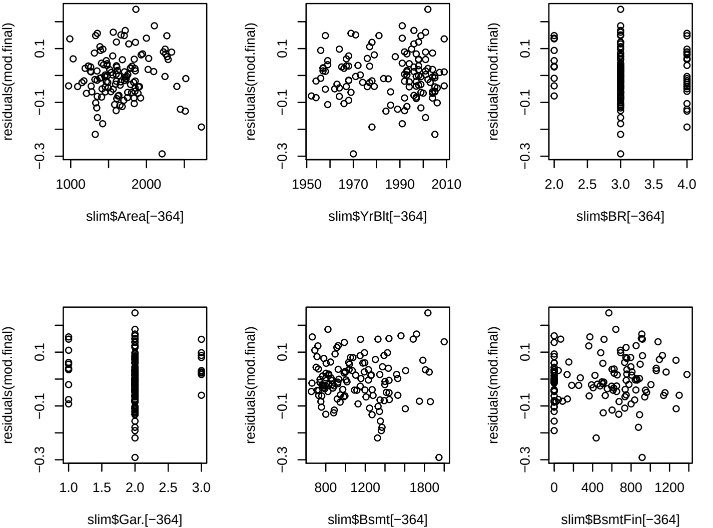
Results

	Response	Interactions	Criterion	sqrt(MSE)	Ratio
1	Price	No	AIC	16389	1.20
2	Price	Yes	AIC	519864	1202.62
3	log(Price)	No	AIC	15751	1.10
4	log(Price)	Yes	AIC	18866950	1583997.40
5	Price	No	BIC	17958	1.43
6	Price	Yes	BIC	16158	1.16
7	log(Price)	No	BIC	14991	1.00
8	log(Price)	Yes	BIC	15756	1.10

Diagnostic plots for model 3 using all data



Quadratic terms?



Final model when using all data

Summary of the final model estimated using all observations

```
Call:
lm(formula = formula(mod[[id]]), data = slim)

Residuals:
      Min        1Q    Median        3Q       Max 
-0.291314 -0.050565 -0.003477  0.052854  0.245974 

Coefficients:
             Estimate Std. Error t value Pr(>|t|)    
(Intercept) 3.484e+00  1.072e+00   3.251 0.001494 ** 
Area        2.569e-04  2.436e-05  10.549  < 2e-16 ***
YrBlt       3.998e-03  5.456e-04   7.327 2.97e-11 ***
Bsmt        1.409e-04  2.566e-05   5.492 2.26e-07 ***
BB          5.808e-02  1.668e-02   3.482 0.000696 ***
Gar.        6.636e-02  2.352e-02   2.822 0.005591 ** 
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.08883 on 120 degrees of freedom
Multiple R-squared:  0.7225, Adjusted R-squared:  0.711 
F-statistic:  62.5 on 5 and 120 DF,  p-value: < 2.2e-16
```

Prediction

```
new <- read.csv("Ch12a-new.csv",header=T)
new$YrSld = 2012
exp(predict(mod.final, new, interval="confidence"))

       fit      lwr      upr
1 208047.7 199141.6 217352.1

exp(predict(mod.final, new, interval="prediction"))

       fit      lwr    upr
1 208047.7 173561.7 249386
```

One aspect that has been completely neglected is location of the properties which clearly has a large impact on the fair market value.

Summary

Who would perform a regression like this?

- Buyer
- Seller
- Real estate agent
- Mortgage appraiser
- Tax assessor