

Regression: Model diagnostics

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Outline

- Model validation vs. diagnostics
- Outlier classification and influence
- Model selection

Model validation vs. model diagnostics

Validation: Is my model generalizable?

- ideally: need external test sample
- internal test sample can offer (limited) help in evaluating overfitting

Diagnostics: Does my model fit the data well?

- very hard to automate this process if something isn't quite right
- requires inspection of residuals
- doesn't necessarily require detailed understanding of the model

types of outliers

Some terminology

- ▶ *Outliers* are points that lie away from the cloud of points.
- ▶ Outliers that lie horizontally away from the center of the cloud are called *high leverage* points.
- ▶ High leverage points that actually influence the slope of the regression line are called *influential* points.
- ▶ In order to determine if a point is influential, visualize the regression line with and without the point. Does the slope of the line change considerably? If so, then the point is influential. If not, then it's not an influential point.

Influence

Intuitively, “influence” is a combination of outlying-ness and leverage. More specifically, we can measure the “deletion influence” of each observation: quantify how much $\hat{\beta}$ changes if an observation is left out.

- Mathematically: $|\hat{\beta} - \hat{\beta}_{(-i)}|$
- Cook’s distance is a value we can calculate for each observation in our dataset that measures this deletion influence. (It uses some nice tricks of linear algebra without having to refit the regression iteratively without each point.)

Poverty data

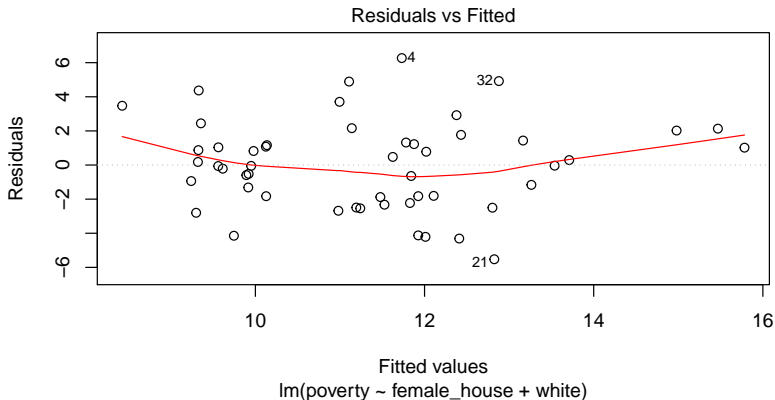
This is a dataset with the % of residents living below the poverty line, as well as some demographic characteristics of states:

- % living in a metro region
- % white
- % high-school graduates
- % with female head-of-household

Example diagnostic plots with poverty data

You can use the `plot.lm()` function to look at leverage, outlying-ness, and influence all together.

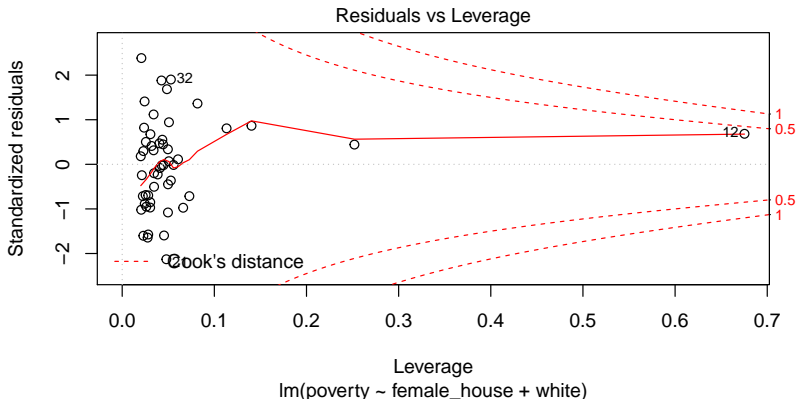
```
mlr = lm(poverty ~ female_house + white, data = poverty)
plot(mlr, which=1)
```



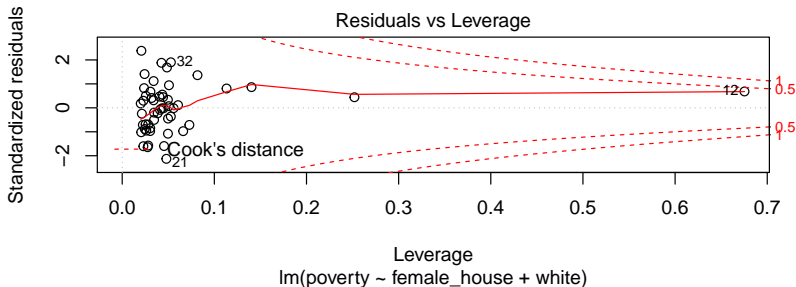
Example diagnostic plots with poverty data

You can use the `plot.lm()` function to look at leverage, outlying-ness, and influence all together.

```
mlr = lm(poverty ~ female_house + white, data = poverty)
plot(mlr, which=5)
```



Investigate identified points!



```
poverty[12,]
```

```
##      state metro_res white hs_grad poverty female_house
## 12 Hawaii      91.5  25.9   88.5    10.6         12.4
```

```
colMeans(poverty[,2:6])
```

```
##      metro_res      white      hs_grad      poverty female_house
##      72.24902      81.71961      86.01176      11.34902      11.63333
```

Model diagnostics summary

You are looking for...

- Points that show worrisome level of influence \implies sensitivity analysis!
- Systematic departures from model assumptions \implies transformations, different model structure
- Unrealistic outliers \implies check your data!

No points show worrisome influence in this poverty data analysis, although observation 12 was high leverage.

model selection

Model selection

Why are you building a model in the first place?

Model selection: considerations

Things to keep in mind...

- **Why am I building a model?** Some common answers
 - ▶ Estimate an association
 - ▶ Test a particular hypothesis
 - ▶ Predict new values
- What predictors will I allow?
- What predictors are needed?

Different answers to these questions will yield different final models.

Model selection: realities

All models are wrong. Some are more useful than others.

- George Box

- In practice, issues with sample size, collinearity (highly correlated predictor variables), and limited available predictors are real problems.
- There is not a single best algorithm for model selection! It pretty much always requires thoughtful reasoning and knowledge about the data at hand.
- When in doubt (unless you are specifically “data mining”), err on the side creating a process that does not require choices being made (by you or the computer) about which covariates to include.

Basic ideas for model selection

For association studies, when your sample size is large

- Include key covariates of interest.
- Include covariates needed because they might be confounders.
- Include covariates that your colleagues/reviewers/collaborators will demand be included for face validity.
- Do NOT go on a fishing expedition for significant results!
- Do NOT use “stepwise selection” methods!
- Subject the selected model to model checking/diagnostics, possibly adjust model structure (i.e. include non-linear relationships with covariates) as needed.

Basic ideas for model selection

For association studies, when your sample size is small

- Same as above, but may need to be more frugal with how many predictors you include.
- Rule of thumb for multiple linear regression is to have at least 15 observations for each covariate you include in your model.