Ch 2.1: What is Statistical Learning?

Lecture 2 - CMSE 381

Prof. Elizabeth Munch

Michigan State University
::
Dept of Computational Mathematics, Science & Engineering

Fri, Sep 2, 2022

Announcements

Last time:

- Discussed where to find everything
  - Github
  - Slack
  - D2L
- Check out the syllabus!

Lec #		Date	Topic	Reading	Homeworks
1	W	Aug 31	Intro / First day stuff / Python Review Pt 1	1	
2	F	Sep 2	What is statistical learning? / Python Review Pt 2	2.1	
	M	Sep 5	No class - Labor day		
3	W	Sep 7	Assessing Model Accuracy	2.2	HW #1 Due
4	F	Sep 9	Linear Regression	3.1	
5	M	Sep 12	More Linear Regression	3.2	
6	W	Sep 14	Even more linear regression	3.3	HW #2 Due
7	F	Sep 16	Probably more linear regression		

Announcements:

- Get on slack!
  - +1 point on the first homework if you post a gif in the thread
- First homework due Weds Sep 7
- First office hours next week

Covered in this class

- Input/output variables
- Prediction vs inference
- Reduceable vs irreduceable error
- Overfitting
- Classification vs regression
- Supervised vs Unsupervised learning

- Please note: no jupyter notebook for today's class, slides only

An example data set: `Advertising`

	TV	Radio	Newspaper	Sales
1	230.1	37.8	69.2	22.1
2	44.5	39.3	45.1	10.4
3	17.2	45.9	69.3	9.3
4	151.5	41.3	58.5	18.5
5	180.8	10.8	58.4	12.9
6	8.7	48.9	75	7.2
7	57.5	32.8	23.5	11.8
8	120.2	19.6	11.6	13.2
9	8.6	2.1	1	4.8
10	199.8	2.6	21.2	10.6
11	66.1	5.8	24.2	8.6

- Sales of a product in 200 markets, along with amount spent on three diffent types of advertising
- Goal:
- Input variables:
- Output variable:

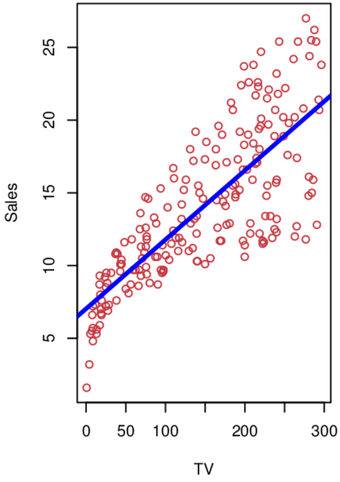
Data available at
https://github.com/nguyen-toan/ISLR/blob/master/dataset/Advertising.csv

Notation and Big Assumption

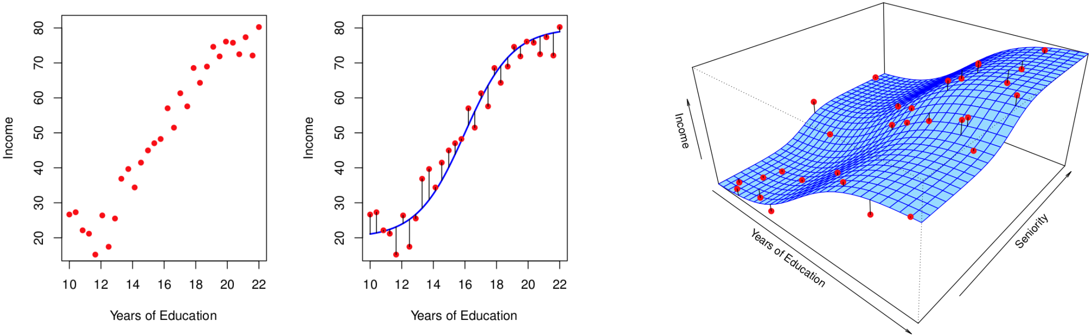
Input variables: $X_1, X_2, \cdots, X_p$
Output variable: Y

$$Y = f(X) + \varepsilon$$

Advertising Example



More examples



Section 1

Prediction vs Inference

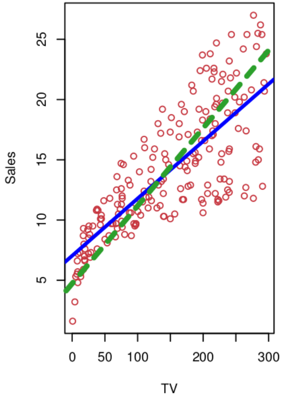
Prediction

Given a value X, try to provide an estimate for $f(X)$.

Build a model:

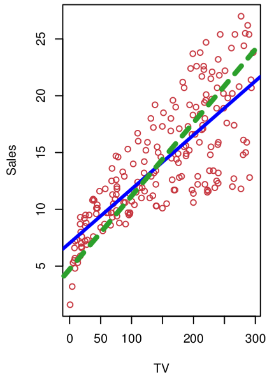
$$\hat{Y} = \hat{f}(X)$$

Example: If we spend \$150 on TV advertising, what will we make in sales?



Group question:

	TV	Radio	Newspaper	Sales
1	230.1	37.8	69.2	22.1
2	44.5	39.3	45.1	10.4
3	17.2	45.9	69.3	9.3



- What is the predicted sales for the first three data points using the green dashed line $\hat{f}$ shown in the graph?

Reduceable vs irreducable error

All models are wrong, some are useful.

$$Y - \hat{Y}$$

Reducible Error

Irreducible Error

More on error

- Given estimate $\hat{f}$ (fixed)
- Set of predictors X (fixed)
- Prediction $\hat{Y} = \hat{f}(X)$

$$E(Y - \hat{Y})^2 =$$

Inference

Want f, but not for prediction (or possibly combined with prediction)

- Which predictors are associated with the response?
- What is the relationship between the response and each predictor?
- Can the relationship between Y and each predictor be adequately summarized using a linear equation? Is it more complicated?

Determine whether each scenario is prediction, inference, or both.

Application	**Prediction**	**Inference**
Identify risk factors for getting long covid.		
Predict effectiveness of vaccine		
Determine the address written in the image of an envelope.		
Speech recognition		
Predict stock prices		

Section 2

How to estimate f?

Input: Training data

- n data points observed
- x_{ij} is the jth predictor for observation i
- y_i is the response variable for the ith observation
- Training data:
  - $\{(x_1, y_1), (x_2, y_2), \cdots, (x_n, y_n)\}$
  - $x_i = (x_i, x_{i2}, \cdots, x_{ip})^T$

	TV	Radio	Newspaper	Sales
1	230.1	37.8	69.2	22.1
2	44.5	39.3	45.1	10.4
3	17.2	45.9	69.3	9.3
4	151.5	41.3	58.5	18.5
5	180.8	10.8	58.4	12.9
6	8.7	48.9	75	7.2
7	57.5	32.8	23.5	11.8
8	120.2	19.6	11.6	13.2
9	8.6	2.1	1	4.8
10	199.8	2.6	21.2	10.6
11	66.1	5.8	24.2	8.6

Parametric methods

Step 1: Select a model

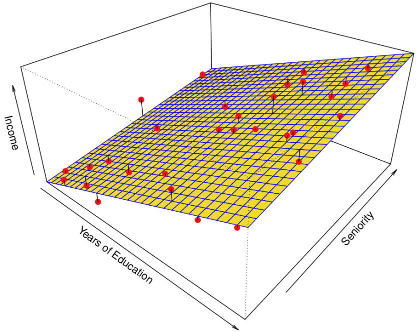
Example:

$$f(X) = \beta_0 + \beta_1 X_2 + \beta_2 X_2 + \cdots + \beta_p X_p$$

Step 2: Train the model

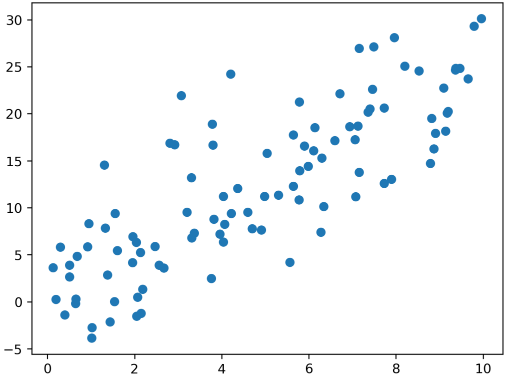
Example:
Find $\beta_i' s$ so that

$$Y \approx \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_p X_p$$



How do you decide on the coefficients?

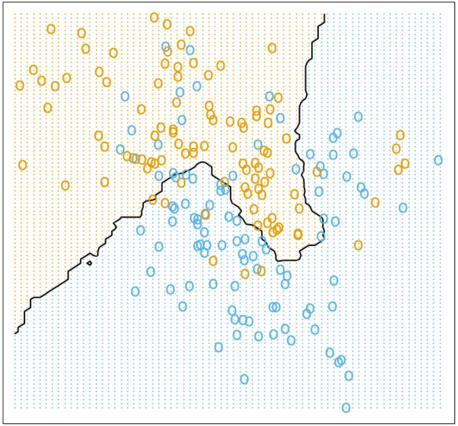
$$Y \approx \beta_0 + \beta_1 X_1 + \beta_2 X_2$$



Example Non-parametric method: Nearest Neighbors

$N_k(x) = \text{Set of } k \text{ nearest neighbors of } x$

$$\hat{f}(x) = \frac{1}{k} \sum_{x_i \in N_k(x)} y_i$$



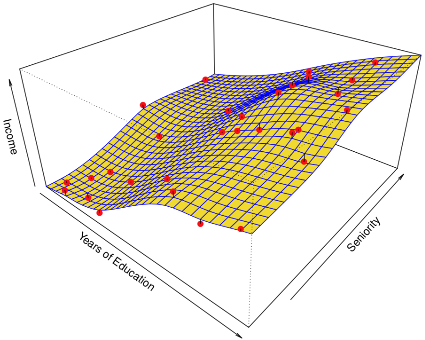
$k = 15$

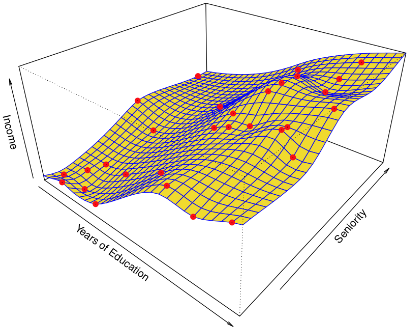
Parametric methods: Pros and Cons

Pros

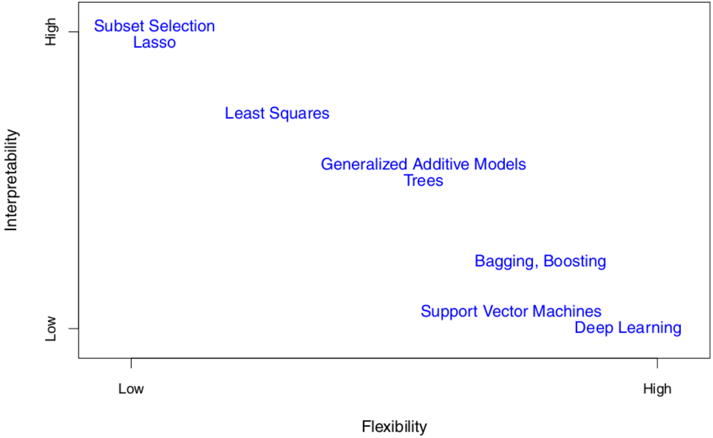
Cons

Overfitting

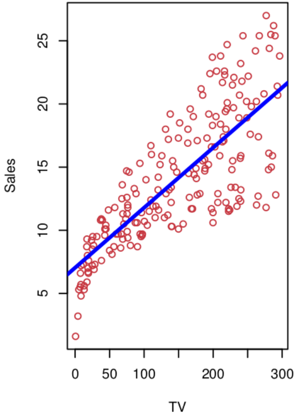




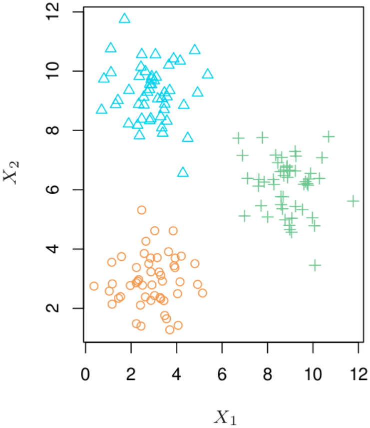
Prediction Accuracy vs Model Interpretability



Supervised learning: Training data has response variable y for every input x



Unsupervised Learning: Training data has response variable y for every input x



Regression vs Classification

Types of variables:

- Quantitative

- Qualitative / Categorical

Section 3

Group work

(a) We collect a set of data on the top 500 firms in the US. For each firm we record profit, number of employees, industry and the CEO salary. We are interested in understanding which factors affect CEO salary.

- Is this classification or regression?
- Do we want inference or prediction?
- What is n, the number of data points?
- What is p, the number of variables?

(b) We are considering launching a new product and wish to know whether it will be a success or a failure. We collect data on 20 similar products that were previously launched. For each product we have recorded whether it was a success or failure, price charged for the product, marketing budget, competition price, and ten other variables.

- Is this classification or regression?
- Do we want inference or prediction?
- What is n, the number of data points?
- What is p, the number of variables?

TL;DR

Wrap up

Next time:

- Monday:
  - No class: Labor day!
- Wednesday:
  - More computer stuff, bring laptop
  - First homework due Sep 7

Lec #		Date	Topic	Reading	Homeworks
1	W	Aug 31	Intro / First day stuff / Python Review Pt 1	1	
2	F	Sep 2	What is statistical learning? / Python Review Pt 2	2.1	
	M	Sep 5	No class - Labor day		
3	W	Sep 7	Assessing Model Accuracy	2.2	HW #1 Due
4	F	Sep 9	Linear Regression	3.1	
5	M	Sep 12	More Linear Regression	3.2	
6	W	Sep 14	Even more linear regression	3.3	HW #2 Due
7	F	Sep 16	Probably more linear regression		

Announcements:

- Get on slack!
  - +1 point on the first homework if you post a gif in the thread
- First office hours next week, will be posted on slack