Week 1, video 3:

Classifiers, Part 1

Prediction

- Develop a model which can infer a single aspect of the data (predicted variable) from some combination of other aspects of the data (predictor variables)

- Sometimes used to predict the future
- Sometimes used to make inferences about the present

Classification

- There is something you want to predict ("the label")
- The thing you want to predict is categorical
  - The answer is one of a set of categories, not a number
  - CORRECT/WRONG (sometimes expressed as 0,1)
    - We'll talk about this specific problem later in the course within latent knowledge estimation
  - HELP REQUEST/WORKED EXAMPLE REQUEST/ATTEMPT TO SOLVE
  - WILL DROP OUT/WON'T DROP OUT
  - WILL ENROLL IN MOOC A,B,C,D,E,F, or G

Where do those labels come from?

- In-software performance
- School records
- Test data
- Survey data
- Field observations or video coding
- Text replays

Classification

- Associated with each label are a set of “features”, which maybe you can use to predict the label

Skill	pknow	time	totalactions	right
ENTERINGGIVEN	0.704	9	1	WRONG
ENTERINGGIVEN	0.502	10	2	RIGHT
USEDIFFNUM	0.049	6	1	WRONG
ENTERINGGIVEN	0.967	7	3	RIGHT
REMOVECOEFF	0.792	16	1	WRONG
REMOVECOEFF	0.792	13	2	RIGHT
USEDIFFNUM	0.073	5	2	RIGHT
….				

Classification

- The basic idea of a classifier is to determine which features, in which combination, can predict the label

Skill	pknow	time	totalactions	right
ENTERINGGIVEN	0.704	9	1	WRONG
ENTERINGGIVEN	0.502	10	2	RIGHT
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….				

Classifiers

- There are hundreds of classification algorithms

- A good data mining package will have many implementations
  - RapidMiner
  - SAS Enterprise Miner
  - Weka
  - KEEL

Classification

- Of course, usually there are more than 4 features
- And more than 7 actions/data points

Domain-Specificity

- Specific algorithms work better for specific domains and problems
- We often have hunches for why that is
- But it's more in the realm of "lore" than really "engineering"

Some algorithms I find useful

- Step Regression
- Logistic Regression
- J48/C4.5 Decision Trees
- JRip Decision Rules
- K* Instance-Based Classifiers

- There are many others!

Step Regression

- ***Not step-wise regression***

- Used for binary classification (0,1)

Step Regression

- Fits a linear regression function
  - (as discussed in previous class)
  - with an arbitrary cut-off

- Selects parameters
- Assigns a weight to each parameter
- Computes a numerical value

- Then all values below 0.5 are treated as 0, and all values >= 0.5 are treated as 1

Example

- $Y = 0.5a + 0.7b - 0.2c + 0.4d + 0.3$
- Cut-off 0.5

a	b	c	d	Y
1	1	1	1	
0	0	0	0	
-1	-1	1	3	

Example

- $Y = 0.5a + 0.7b - 0.2c + 0.4d + 0.3$
- Cut-off 0.5

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1	1	1	1	1
0	0	0	0	0
-1	-1	1	3	0

Quiz

- $Y = 0.5a + 0.7b - 0.2c + 0.4d + 0.3$
- Cut-off 0.5

a	b	c	d	Y
2	-1	0	1	

Note

- Step regression is used in RapidMiner by using linear regression with binary data

- Other functions in different packages

Step regression: should you use it?

- Step regression is not preferred by statisticians due to lack of closed-form expression

- But often does better in EDM, due to lower over-fitting

Logistic Regression

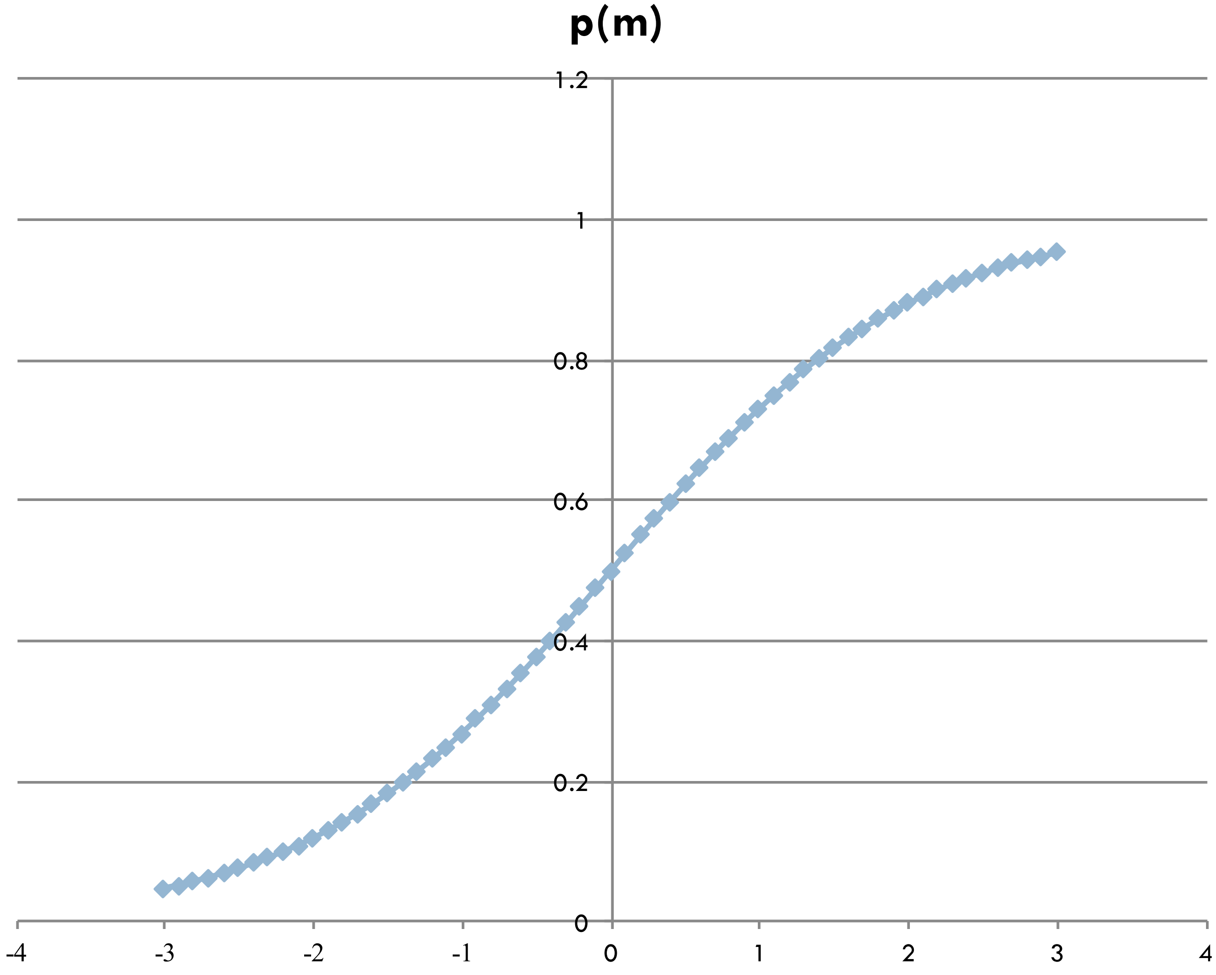
- Another algorithm for binary classification (0,1)

Logistic Regression

- Given a specific set of values of predictor variables

- Fits logistic function to data to find out the frequency/odds of a specific value of the dependent variable

Logistic Regression



Logistic Regression

m = a0 + a1v1 + a2v2 + a3v3 + a4v4…

$$\mathrm{p}(m) = \frac{1}{1 + e^{-m}}$$

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1 + e^{-m}}$$

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1 + e^{-m}}$$

A	B	C	M	P(M)
0	0	0		

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1 + e^{-m}}$$

A	B	C	M	P(M)
0	0	0	0	0.5

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1+e^{-m}}$$

A	B	C	M	P(M)
1	1	1	1	0.73

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1+e^{-m}}$$

A	B	C	M	P(M)
-1	-1	-1	-1	0.27

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1 + e^{-m}}$$

A	B	C	M	P(M)
2	2	2	2	0.88

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1 + e^{-m}}$$

A	B	C	M	P(M)
3	3	3	3	0.95

Logistic Regression

m = 0.2A + 0.3B

$$p(m) = \frac{1}{1+e^{-m}}$$

A	B	C	M	P(M)
50	50	50	50	~1

Relatively conservative

- Thanks to simple functional form, is a relatively conservative algorithm
  - I'll explain this in more detail later in the course

Good for

- Cases where changes in value of predictor variables have predictable effects on probability of predicted variable class
- $m = 0.2A + 0.3B + 0.5C$
- Higher A always leads to higher probability
  - But there are some data sets where this isn't true!

What about interaction effects?

- A = Bad
- B = Bad
- A+B = Good

What about interaction effects?

- Ineffective Educational Software = Bad
- Off-Task Behavior = Bad
- Ineffective Educational Software **PLUS**
  Off-Task Behavior = Good

Logistic and Step Regression are good when interactions are not particularly common

- Can be given interaction effects through automated feature distillation
  - We'll discuss this later

- But is not particularly optimal for this

What about interaction effects?

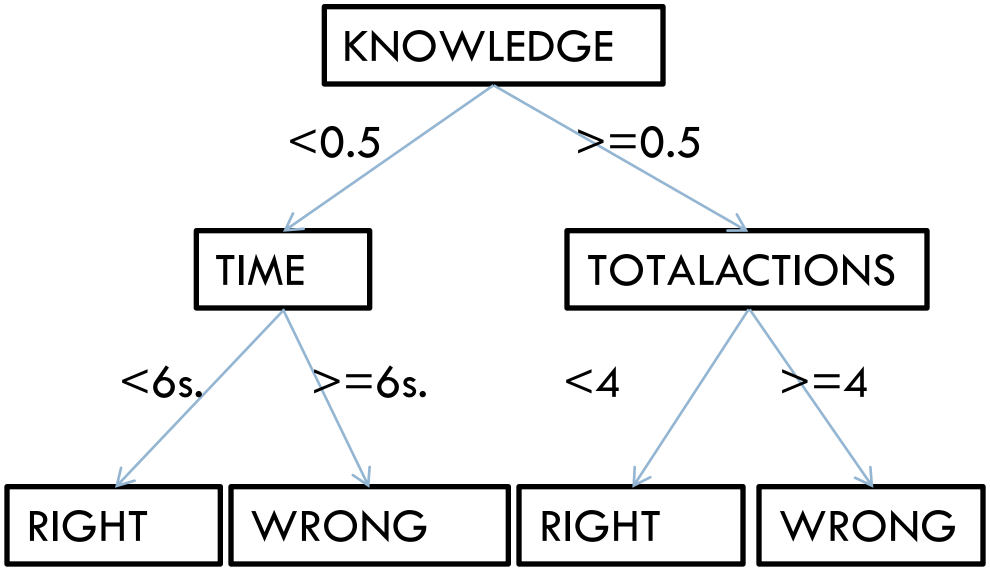
- Fast Responses + Material Student Already Knows -> Associated with Better Learning

- Fast Responses + Material Student Does not Know -> Associated with Worse Learning

Decision Trees

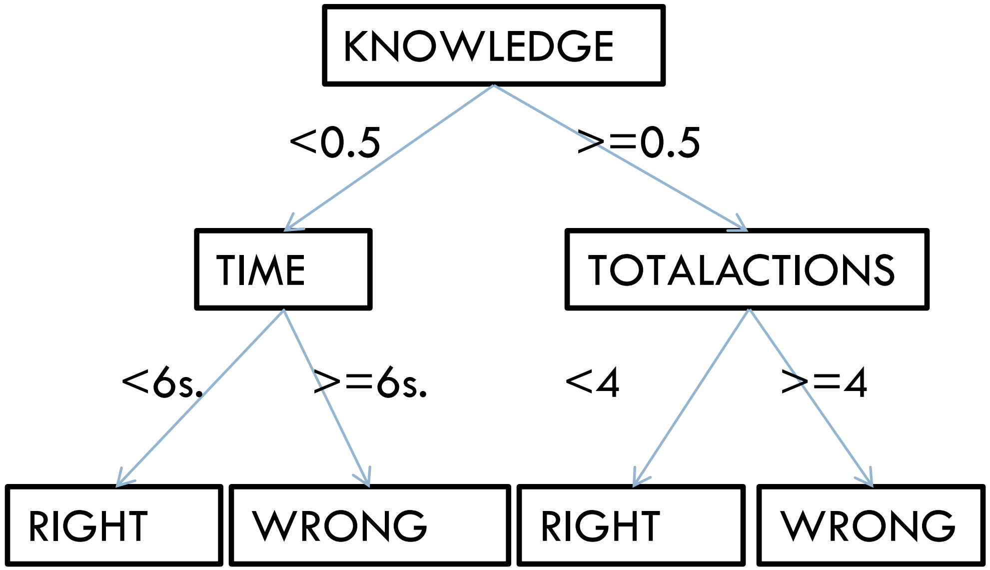
- An approach that explicitly deals with interaction effects

Decision Tree



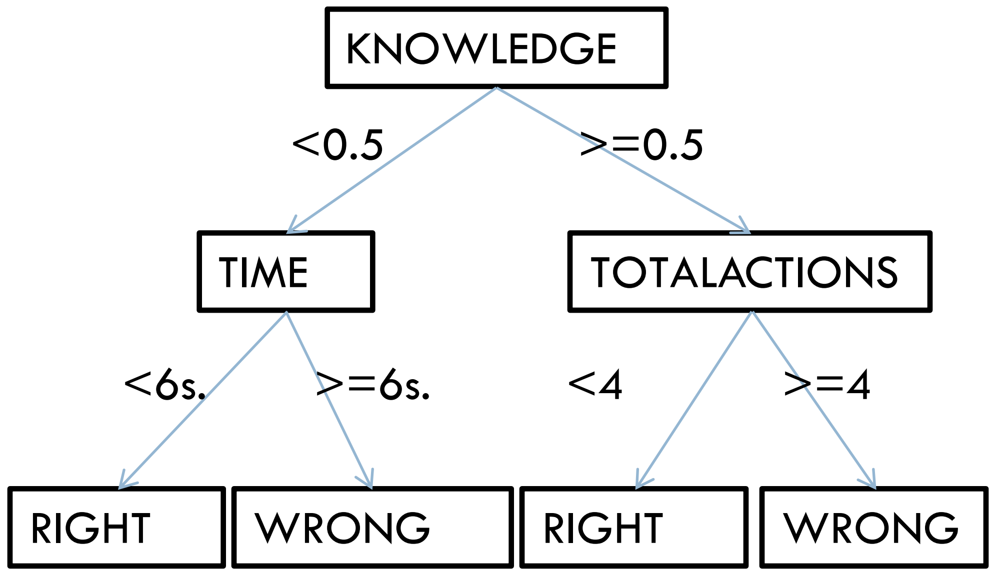
Skill	knowledge	time	totalactions	right?
COMPUTESLOPE	0.544	9	1	?

Decision Tree



Skill	knowledge	time	totalactions	right?
COMPUTESLOPE	0.544	9	1	RIGHT

Decision Tree



Skill	knowledge	time	totalactions	right?
COMPUTESLOPE	0.444	9	1	?

Decision Tree Algorithms

- There are several

- I usually use J48, which is an open-source re-implementation in Weka/RapidMiner of C4.5 (Quinlan, 1993)

J48/C4.5

- Can handle both numerical and categorical predictor variables
  - Tries to find optimal split in numerical variables
- Repeatedly looks for variable which best splits the data in terms of predictive power for each variable
- Later prunes out branches that turn out to have low predictive power
- Note that different branches can have different features!

Can be adjusted…

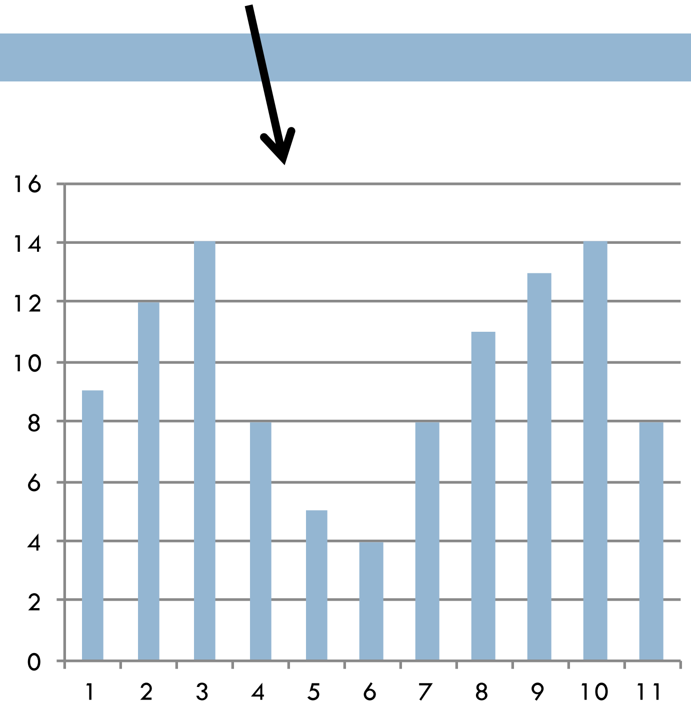
- To split based on more or less evidence

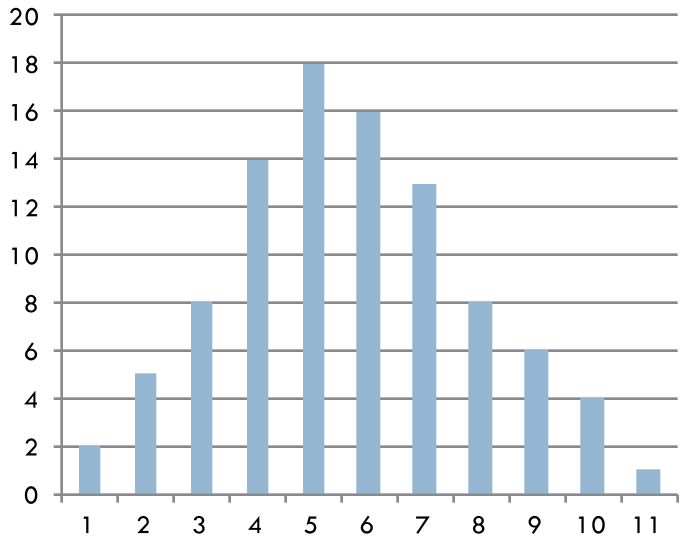
- To prune based on more or less predictive power

Relatively conservative

- Thanks to pruning step, is a relatively conservative algorithm
  - We'll discuss conservatism in a later class

Good when data has natural splits





Good when multi-level interactions are common

Good when same construct can be arrived at in multiple ways

- A student is likely to drop out of college when he
  - Starts assignments early but lacks prerequisites

- OR when he
  - Starts assignments the day they're due

What variables should you use?

What variables should you use?

- In one sense, the entire point of data mining is to figure out which variables matter

- But some variables have more construct validity or theoretical justification than others – using those variables generally leads to more generalizable models
  - We'll talk more about this in a future lecture

What variables should you use?

- In one sense, the entire point of data mining is to figure out which variables matter

- More urgently, some variables will make your model general only to the data set where they were trained
  - These should not be included in your model
  - They are typically the variables you want to test generalizability across during cross-validation
    - More on this later

Example

- Your model of student off-task behavior should not depend on which student you have
- “If student = BOB, and time > 80 seconds, then…”
- This model won’t be useful when you’re looking at totally new students

Example

- Your model of student off-task behavior should not depend on which college the student is in
- "If school = University of Pennsylvania, and time > 80 seconds, then…"
- This model won't be useful when you're looking at data from new colleges

Note

- In modern statistics, you often need to explicitly include these types of variables in models to conduct valid statistical testing
- This is a ***difference*** between classification and statistical modeling
- We'll discuss it more in future lectures

Later Lectures

- More classification algorithms
- Goodness metrics for comparing classifiers
- Validating classifiers for generalizability
- What does it mean for a classifier to be conservative?

Next Lecture

- Building regressors and classifiers in RapidMiner