Classification:
Analyzing Sentiment

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Predicting sentiment by topic: *An intelligent restaurant review system*

It’s a big day & I want to book a table at a nice Japanese restaurant

Seattle has many ★★★★ sushi restaurants

What are people saying about the food? the ambiance?...

Positive reviews not positive about everything

Sample review:

Watching the chefs create incredible edible art made the experience very unique.

My wife tried their ramen and it was pretty forgettable.

All the sushi was delicious! Easily best sushi in Seattle.

Experience

From reviews to topic sentiments

All reviews
for restaurant

7/21/2015

This is probably my favorite place to eat Japanese in Seattle. My boyfriend and I ordered nigiri of scallop, Japanese snapper (seasonal), and the agedashi tofu and 2 special rolls. I would skip the special rolls, because the nigiri and sashimi cuts is where this place excels. The tofu, as recommended by other Yelpers was amazing. It's more chewy and the sauce/gravy is the perfect amount of flavor for the delicate tofu.

6/11/2015

Dining here at the sushi bar made me feel like sitting front row to an amazing performance. We didn't have resos, banged down to the ID after work, got here breathlessly at 5:10pm, and got the last two seats in the place.

6/9/2015

I came here having high expectations due to the reviews of this place, but i was bit disappointed.
The restaurant is small so do make reservations when you come here. Dishes cost from $4-26 each and dishes are small.

Novel intelligent restaurant review app

Experience
★★★★

Ramen
★★★

Sushi
★★★★★

Easily best sushi
in Seattle.

Intelligent restaurant review system

All reviews for restaurant

7/21/2015

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Break all reviews into sentences

The seaweed salad was just OK, vegetable salad was just ordinary.

I like the interior decoration and the blackboard menu on the wall.

All the sushi was delicious.

My wife tried their ramen and it was pretty forgettable.

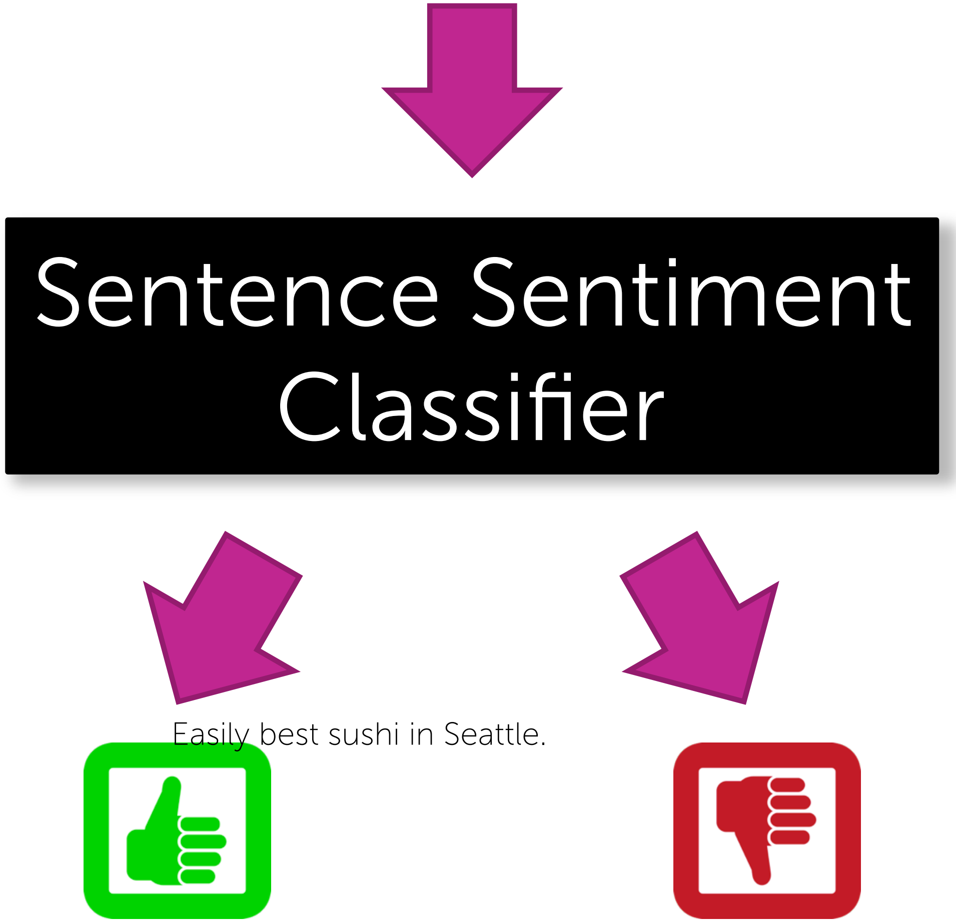
The sushi was amazing, and the rice is just outstanding.

The service is somewhat hectic.

Easily best sushi in Seattle.

Core building block

Easily best sushi in Seattle.



Intelligent restaurant review system

All reviews
for restaurant

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This is probably my favorite place to eat Japanese in Seattle. My boyfriend and I ordered nigiri of scallop, Japanese snapper (seasonal), and the agedashi tofu and 2 special rolls. I would skip the special rolls, because the nigiri and sashimi cuts is where this place excels. The tofu, as recommended by other Yelpers was amazing. It's more chewy and the sauce/gravy is the perfect amount of flavor for the delicate tofu.

8/11/2015
All the sushi was delicious.
Dining here at the sushi bar made me feel like sitting front row to an amazing performance. We didn't have resos, banged down to the ID after work, got here breathlessly at 5:10pm, and got the last two seats in the place.

6/9/2015
The sushi was amazing, and the rice is just outstanding.

Easily best sushi in Seattle.

Break all reviews into sentences

Select sentences about "sushi"

The seaweed salad was just OK, vegetable salad was just ordinary.

I like the interior decoration and the blackboard menu on the wall.

All the sushi was delicious.

My wife tried their ramen and it was pretty forgettable.

The sushi was amazing, and the rice is just outstanding.

The service is somewhat hectic.

Easily best sushi in Seattle.

Sentence Sentiment Classifier

Average predictions

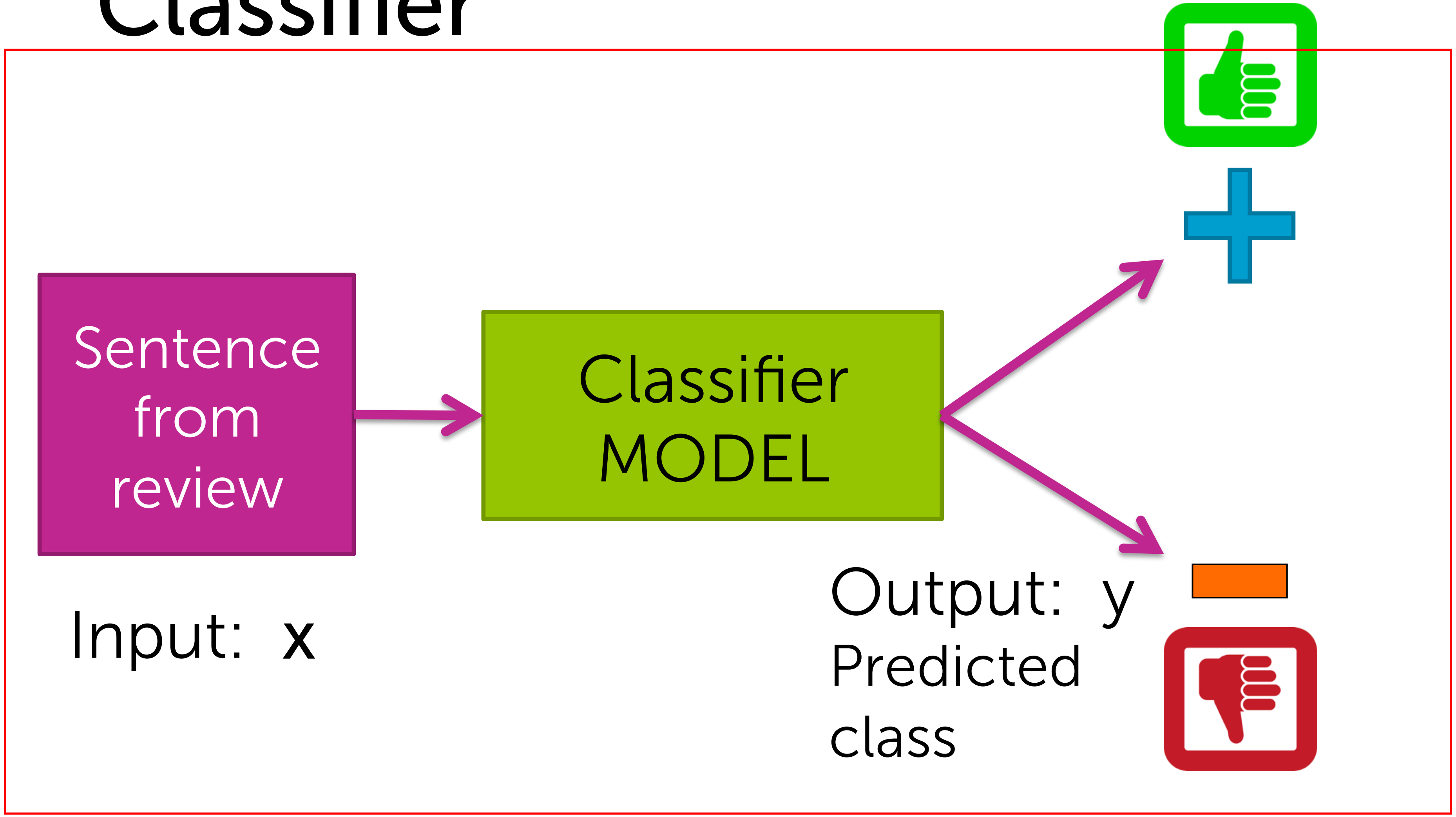
Sushi
★★★★★

Most 👍 & 👎

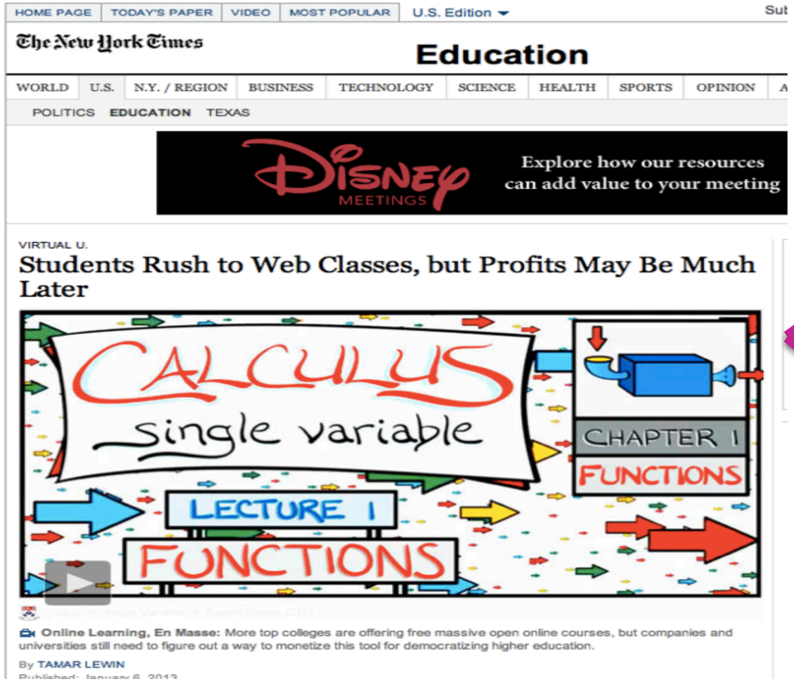
Easily best sushi in Seattle.

Classifier applications

Classifier


Sentence from review
Classifier MODEL
Input: x
Output: y
Predicted class

Example multiclass classifier
Output y has more than 2 categories



Education

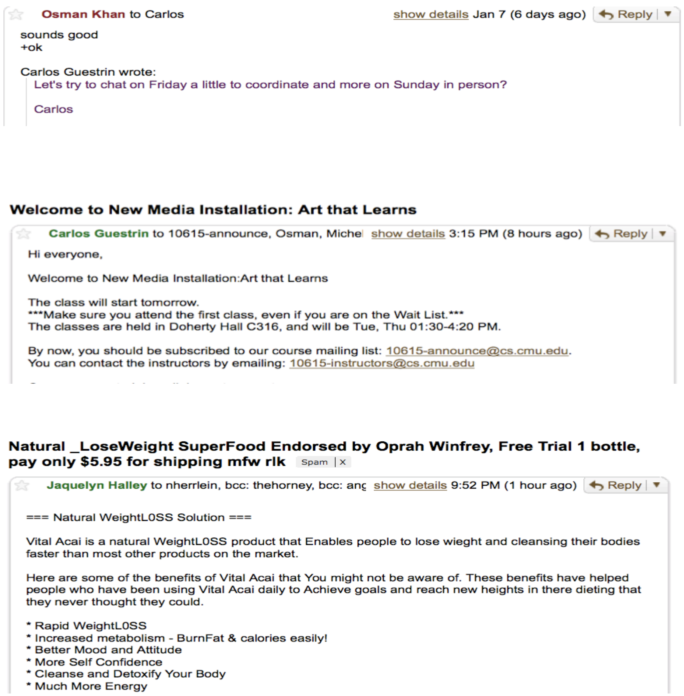
Finance

Technology

Input: x
Webpage

Output: y

Spam filtering


Osman Khan to Carlos show details Jan 7 (6 days ago) Reply
sounds good
+ok
Carlos Guestrin wrote:
Let's try to chat on Friday a little to coordinate and more on Sunday in person?
Carlos

Welcome to New Media Installation: Art that Learns
Carlos Guestrin to 10615-announce, Osman, Michel show details 3:15 PM (8 hours ago) Reply
Hi everyone,
Welcome to New Media Installation:Art that Learns
The class will start tomorrow.
Make sure you attend the first class, even if you are on the Wait List.
The classes are held in Doherty Hall C316, and will be Tue, Thu 01:30-4:20 PM.
By now, you should be subscribed to our course mailing list: 10615-announce@cs.cmu.edu.
You can contact the instructors by emailing: 10615-instructors@cs.cmu.edu

Natural _LoseWeight SuperFood Endorsed by Oprah Winfrey, Free Trial 1 bottle, pay only $5.95 for shipping mfw rlk Spam
Jaquelyn Halley to nherrlein, bcc: thehorney, bcc: anc show details 9:52 PM (1 hour ago) Reply
=== Natural WeightL0SS Solution ===
Vital Acai is a natural WeightL0SS product that Enables people to lose wieght and cleansing their bodies faster than most other products on the market.
Here are some of the benefits of Vital Acai that You might not be aware of. These benefits have helped people who have been using Vital Acai daily to Achieve goals and reach new heights in there dieting that they never thought they could.
* Rapid WeightL0SS
* Increased metabolism - BurnFat & calories easily!
* Better Mood and Attitude
* More Self Confidence
* Cleanse and Detoxify Your Body
* Much More Energy

Not spam

Spam

Input: x

Output: y

Text of email, sender, IP,...

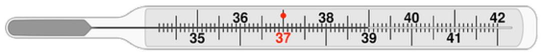
Image classification

Input: x
Image pixels

Output: y
Predicted object

Personalized medical diagnosis

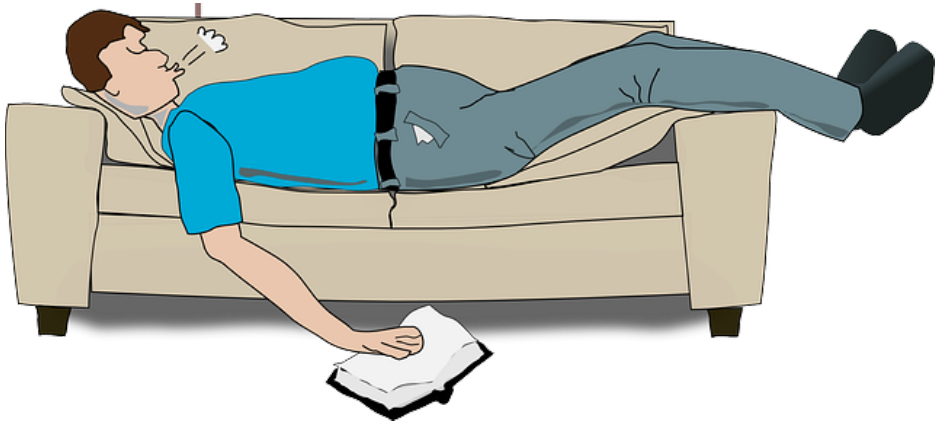
Input: x



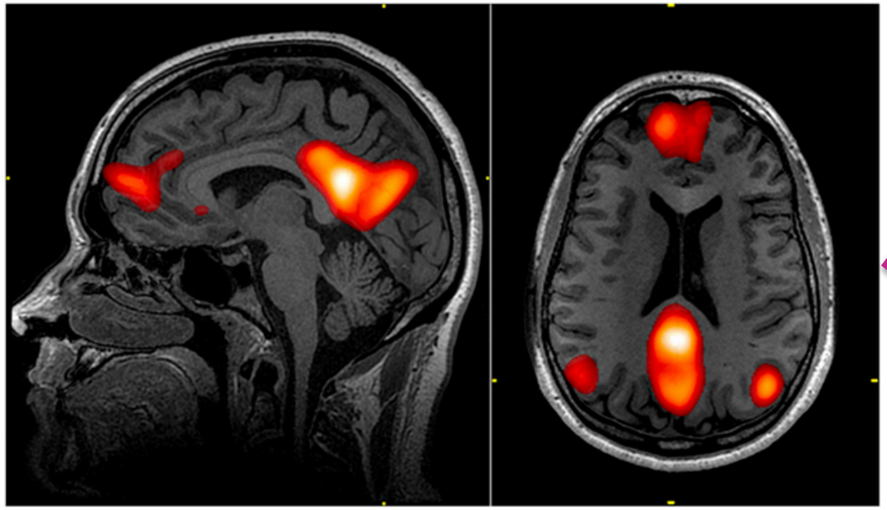
Disease Classifier MODEL

Output: y

- Healthy
- Cold
- Flu
- Pneumonia
- …



Reading your mind

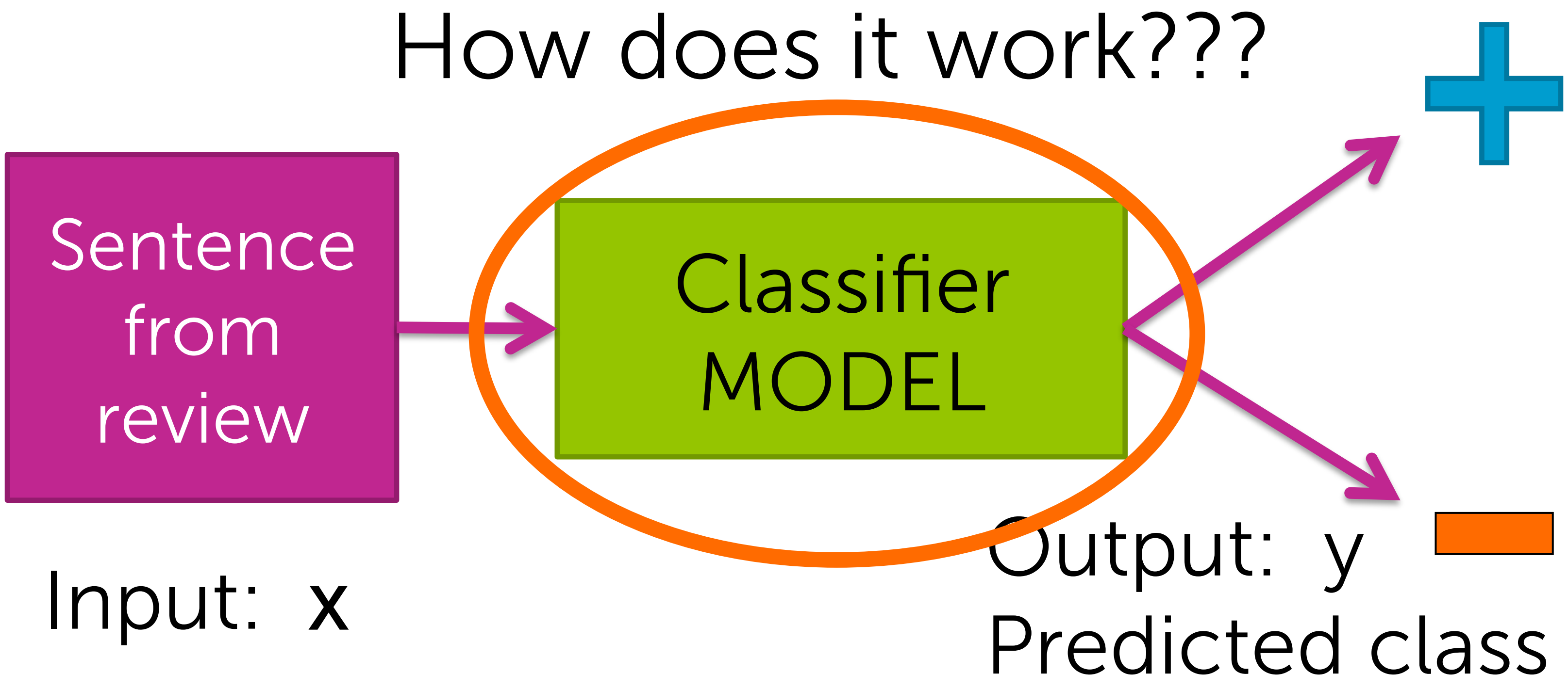


“Hammer”

“House”

Linear classifiers

Representing classifiers



List of positive words	List of negative words
great, awesome, good, amazing,…	bad, terrible, disgusting, sucks,…

Sentence from review

Input: x

Simple threshold classifier

Count positive & negative words in sentence

If *number of positive words > number of negative words*:

$\hat{y}$ = +

Else:

$\hat{y}$ = −

List of positive words	List of negative words
great, awesome, good, amazing,…	bad, terrible, disgusting, sucks,…

Sushi was great, the food was awesome, but the service was terrible.

Simple threshold classifier

Count positive & negative words in sentence

2

If *number of positive words* > *number of negative words*:

$\hat{y}$ = +

1

Else:

$\hat{y}$ = −

Problems with threshold classifier

- How do we get list of positive/negative words?
- Words have different degrees of sentiment:
  - Great > good
  - How do we weigh different words?
- Single words are not enough:
  - *Good* ➔ Positive
  - *Not good* ➔ Negative

Addressed by learning a classifier

Addressed by more elaborate features

A (linear) classifier

- Will use training data to learn a weight for each word

Word	Weight
good	1.0
great	1.5
awesome	2.7
bad	-1.0
terrible	-2.1
awful	-3.3
restaurant, the, we, where, …	0.0
…	…

Scoring a sentence

Word	Weight
good	1.0
great	1.2
awesome	1.7
bad	-1.0
terrible	-2.1
awful	-3.3
restaurant, the, we, where, …	0.0
…	…

Input x:

Sushi was great,
the food was awesome,
but the service was terrible.

$$\text{Score}(x) = 1.2 + 1.7 - 2.1$$
$$= 0.8$$

$$\text{Score}(x) > 0 \Rightarrow +$$

if

$$\text{Score}(x) < 0 \Rightarrow -$$

Called a linear classifier, because output is weighted sum of input.

Word	Weight
…	…

Simple linear classifier

Score(x) = weighted count of words in sentence

If *Score (x) > 0*:
  $\hat{y}$ = +
Else:
  $\hat{y}$ = –

Sentence from review

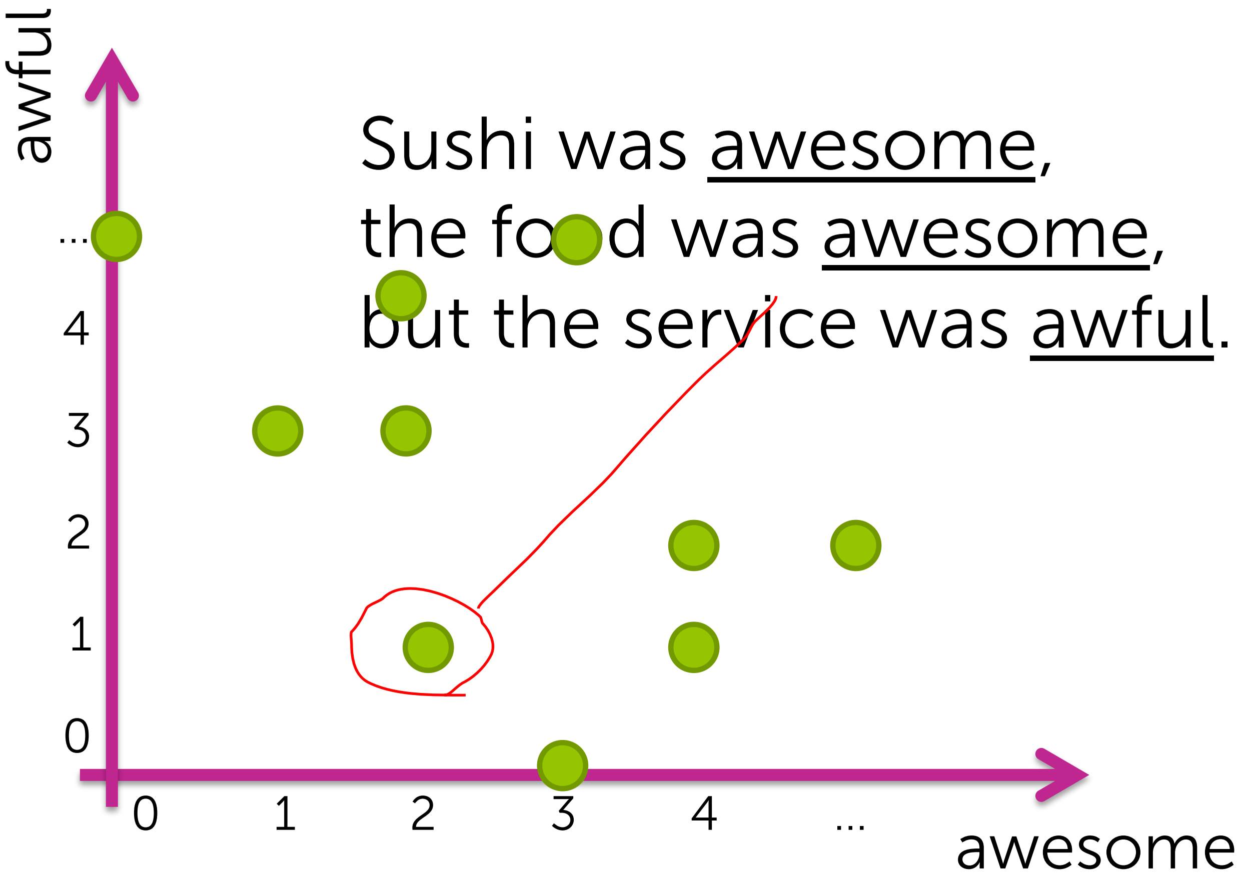
Input: x

Decision boundaries

Suppose only two words had non-zero weight

Word	Weight
awesome	1.0
awful	-1.5

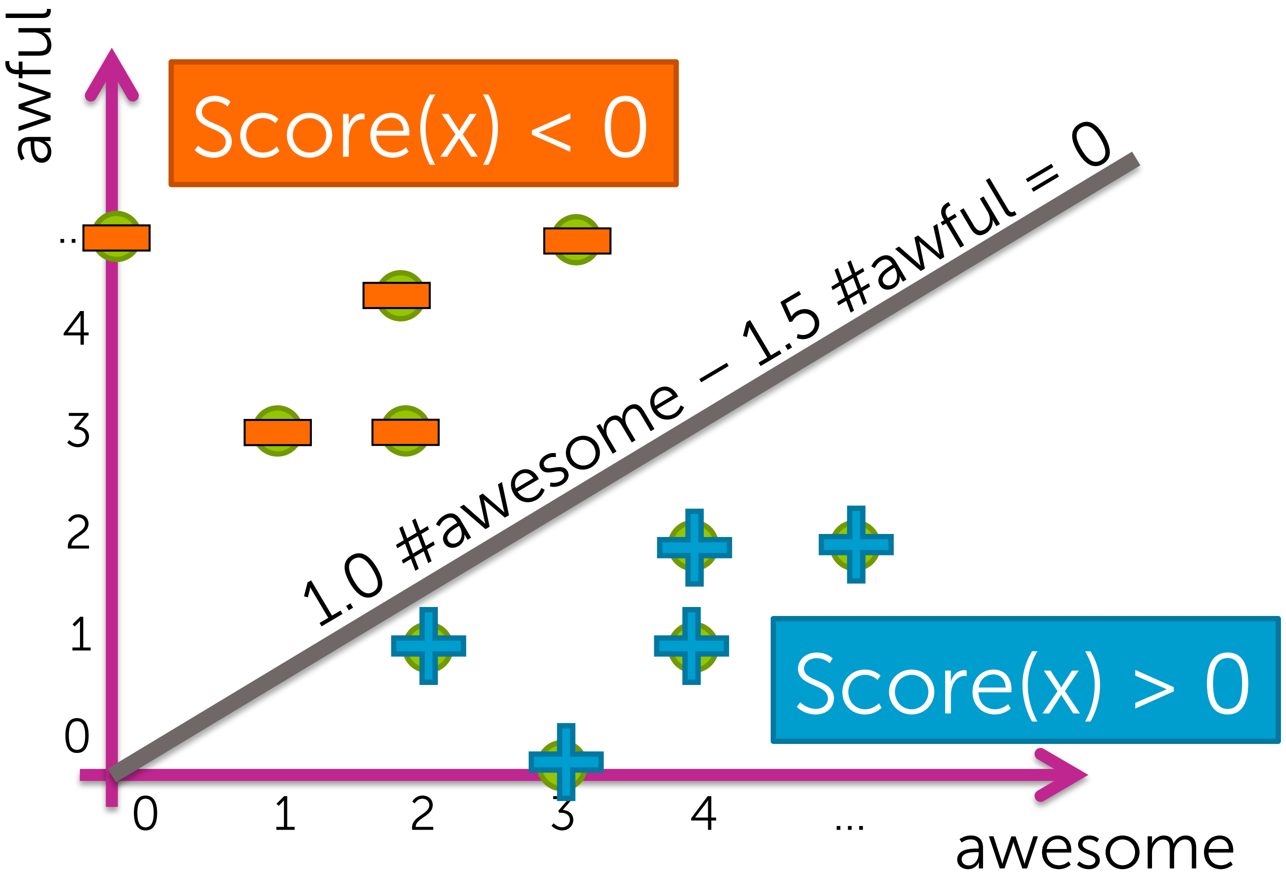
Score(x) = 1.0 #awesome – 1.5 #awful



Decision boundary example

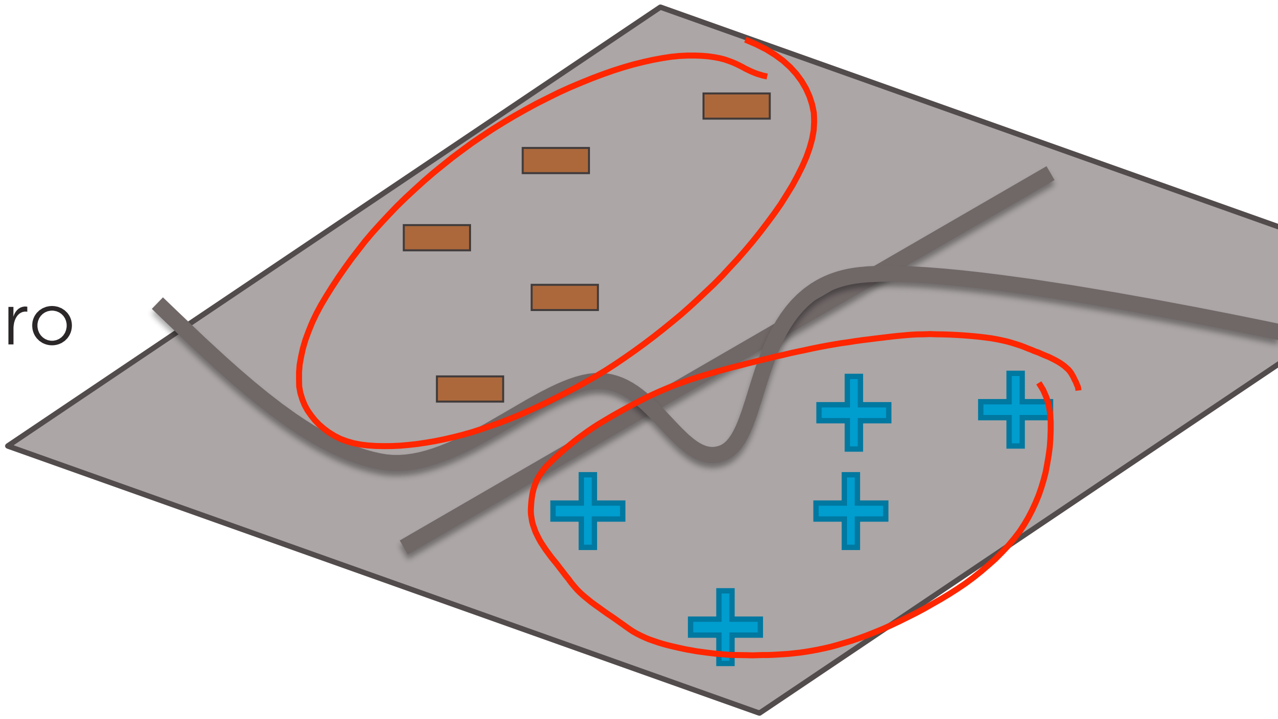
Word	Weight
awesome	1.0
awful	-1.5

Score(x) = 1.0 #awesome – 1.5 #awful



Decision boundary separates positive & negative predictions

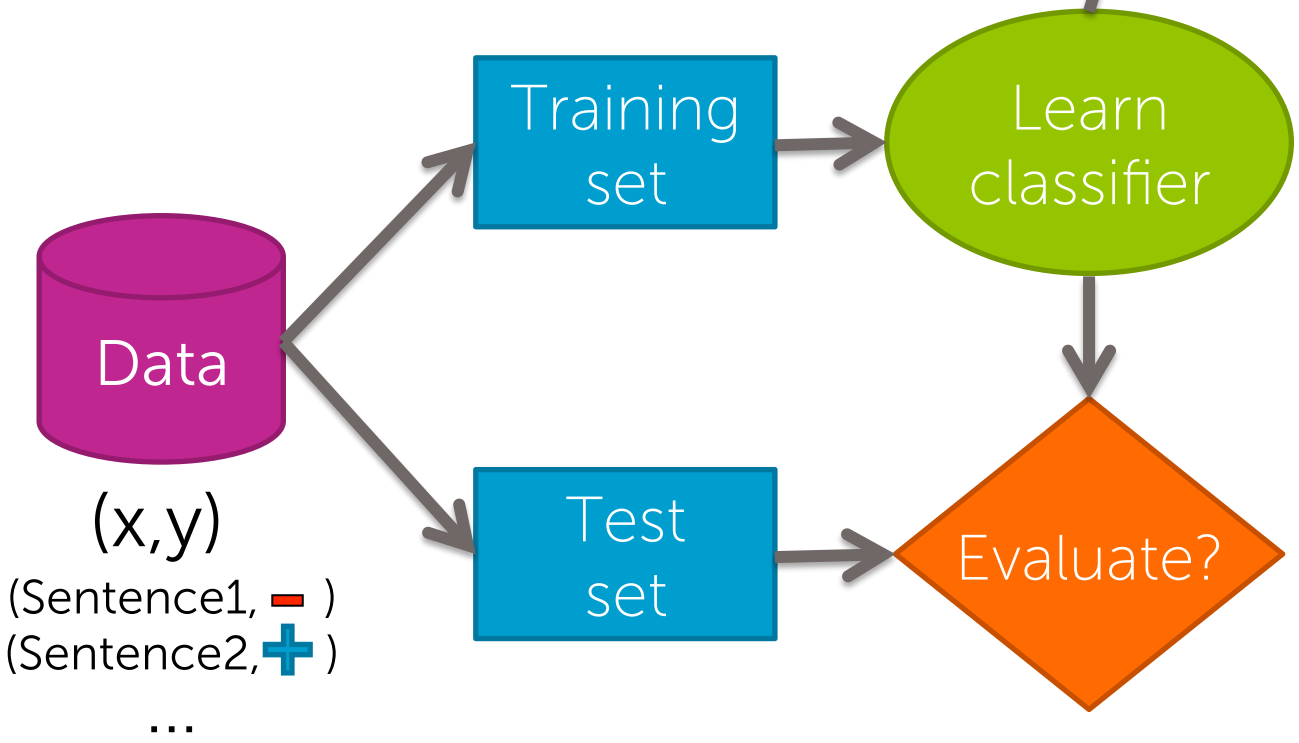
- For linear classifiers:
  - When 2 weights are non-zero
    ➔ line
  - When 3 weights are non-zero
    ➔ plane
  - When many weights are non-zero
    ➔ hyperplane
- For more general classifiers
  ➔ more complicated shapes



Training and evaluating a classifier

Training a classifier = Learning the weights

Word	Weight
good	1.0
awesome	1.7
bad	-1.0
awful	-3.3
…	…



Classification error

Learned classifier

$\hat{y} = +$

Test example

(Sushi was great, +)

(Food was OK, –)

Correct!

Mistake!

Correct	0 / 1
Mistakes	0 / 1

Hide label

Classification error & accuracy

- Error measures fraction of mistakes

$$\text{error} = \frac{\text{\# of mistakes}}{\text{Total \# of Sentences}}$$

  - Best possible value is 0.0

- Often, measure **accuracy**
  - Fraction of correct predictions

$$\text{accuracy} = \frac{\text{\# of Correct}}{\text{Total \# of Sentences}}$$

  - Best possible value is 1.0

What's a good accuracy?

What if you ignore the sentence, and just guess?

- For binary classification:
  - Half the time, you'll get it right! (on average)
    - ➔ accuracy = 0.5

- For k classes, accuracy = 1/k
  - 0.333 for 3 classes, 0.25 for 4 classes,…

At the very, very, very least,
you should healthily beat random…
Otherwise, it's (usually) pointless…

Is a classifier with 90% accuracy good? Depends…

2010 data shows:
"90% emails sent are spam!"

Predicting every email is spam gets you 90% accuracy!!!

Majority class prediction

Amazing performance when there is class imbalance
(but silly approach)

- One class is more common than others
- Beats random (if you know the majority class)

So, always be digging in and asking the hard questions about reported accuracies

- Is there class imbalance?
- How does it compare to a simple, baseline approach?
  - Random guessing
  - Majority class
  - …
- Most importantly: *what accuracy does my application need?*
  - What is good enough for my user's experience?
  - What is the impact of the mistakes we make?

False positives, false negatives, and confusion matrices

Types of mistakes

		Predicted label	
		+	−
True label	+	True Positive	False Negative (FN)
	−	False Positive (FP)	True Negative

Cost of different types of mistakes can be different (& high) in some applications

	Spam filtering	Medical diagnosis
False negative	Annoying	Disease not treated
False positive	Email lost Higher cost	Wasteful treatment

Confusion matrix – binary classification

100 test examples

		Predicted label	
		+	−
True label	+ (60)	50	10
	− (40)	5	35

$$\text{accuracy} = \frac{85}{100} = 0.85$$

Confusion matrix – multiclass classification

100 test examples

Predicted label

True label	Healthy	Cold	Flu
Healthy 70	60	8	2
Cold 20	4	12	4
Flu 10	0	2	8

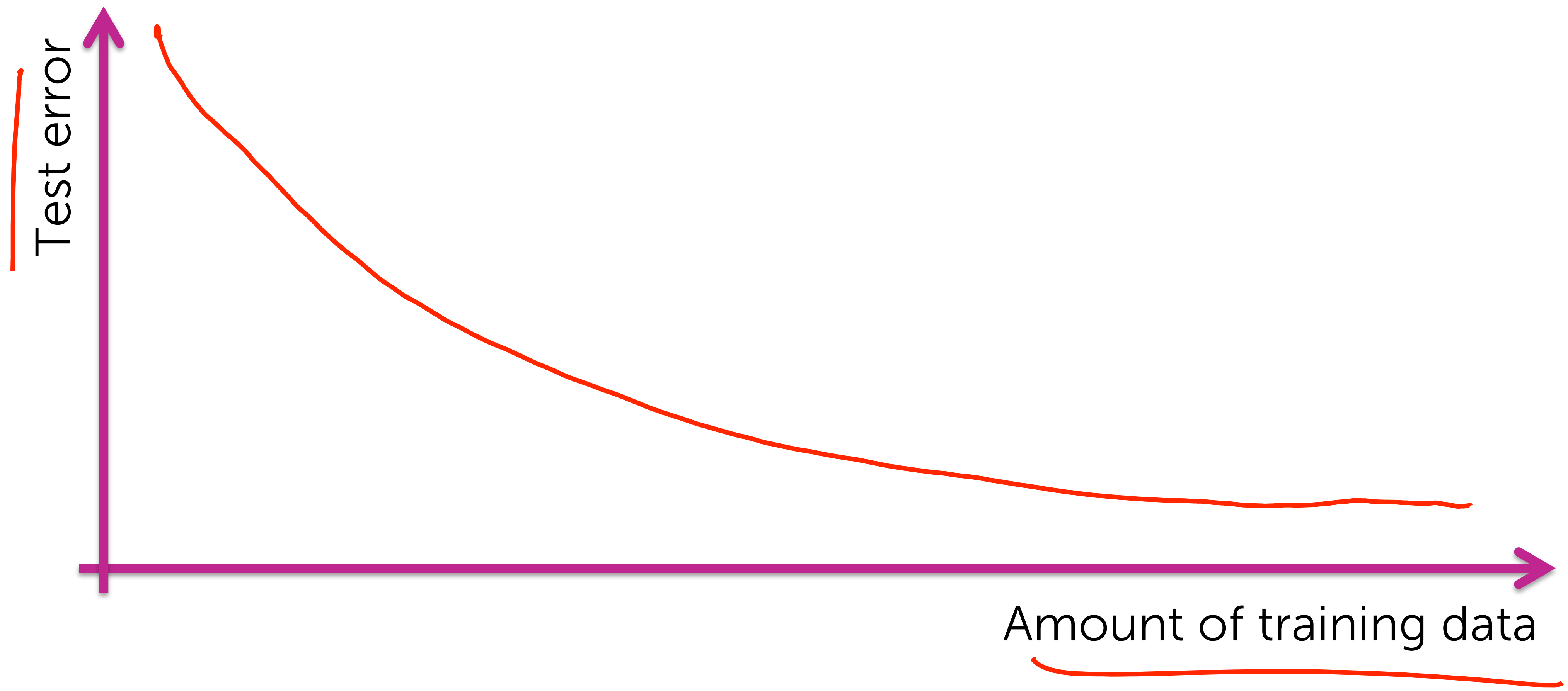
$$\text{accuracy} = \frac{80}{100} = 0.8$$

Learning curves:
How much data do I need?

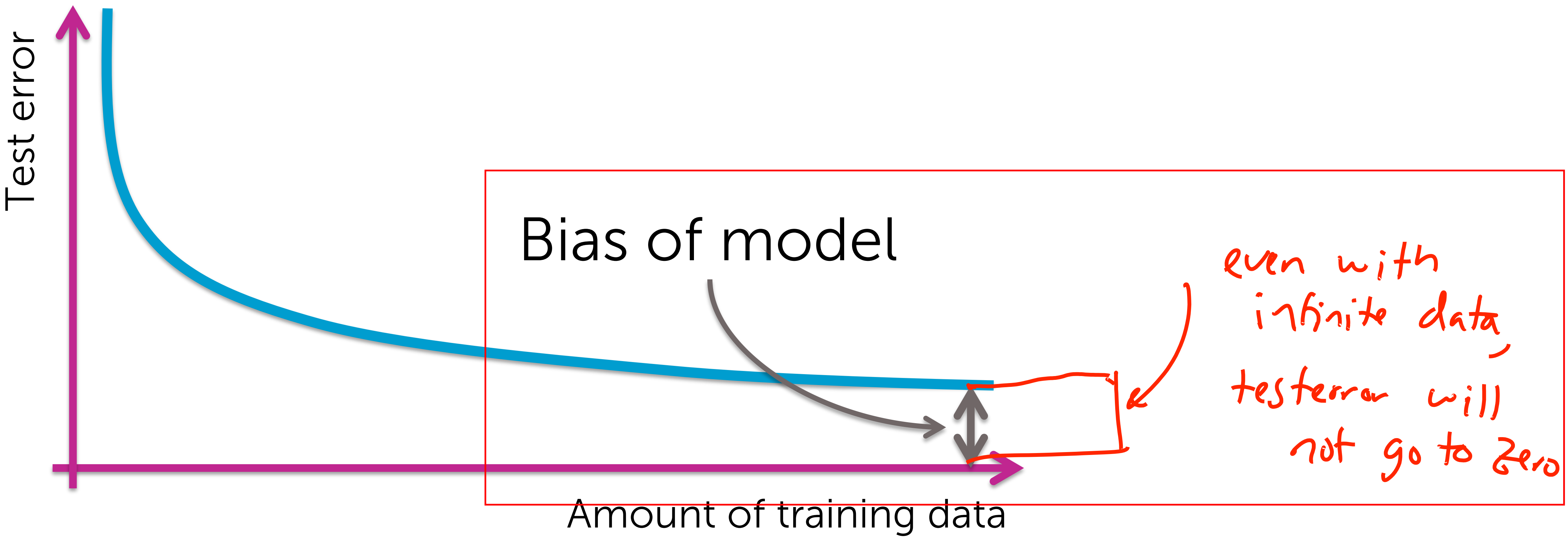
How much data does a model need to learn?

- The more the merrier ☺
  - But data quality is most important factor
- Theoretical techniques sometimes can bound how much data is needed
  - Typically too loose for practical application
  - But provide guidance
- In practice:
  - More complex models require more data
  - Empirical analysis can provide guidance

Learning curves



Is there a limit?
Yes, for most models…



More complex models tend to have less bias…

Sentiment classifier using
single words can do OK, but…

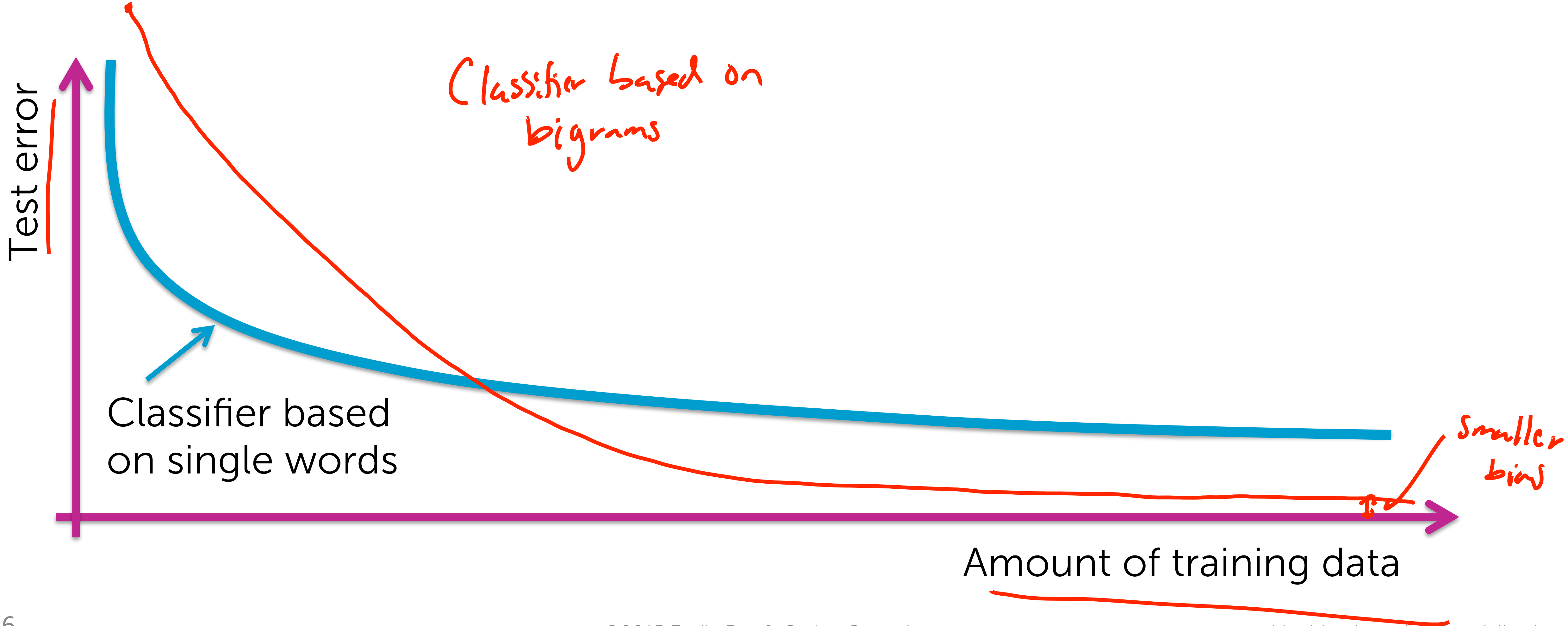
Never classifies correctly:
"The sushi was not good."

More complex model:
consider pairs of words (bigrams)

Word	Weight
good	+1.5
not good	-2.1

Less bias →
potentially more accurate,
needs more data to learn

Models with less bias tend to need more data to learn well, but do better with sufficient data



Class probabilities

How confident is your prediction?

- Thus far, we've outputted a prediction + / –
- But, how sure are you about the prediction?
  - *"The sushi & everything else were awesome!"* ← $P(y=+|x) = 0.99$
  - *"The sushi was good, the service was OK."* ← $P(y=+|x) = 0.55$

Many classifiers provide a confidence level:

$$P(y|x)$$

Output label → y

Input sentence → x

Extremely useful in practice

Summary of classification

What you can do now…

- Identify a classification problem and some common applications
- Describe decision boundaries and linear classifiers
- Train a classifier
- Measure its error
  - Some rules of thumb for good accuracy
- Interpret the types of error associated with classification
- Describe the tradeoffs between model bias and data set size
- Use class probability to express degree of confidence in prediction