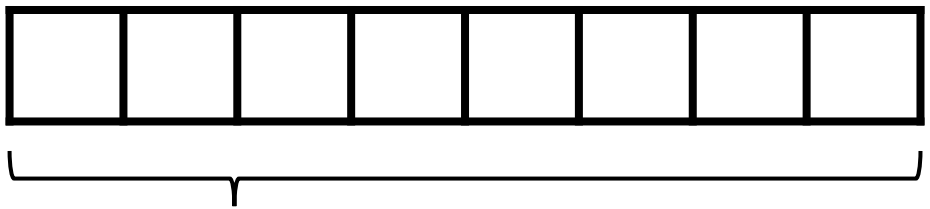
Bag of Words Models

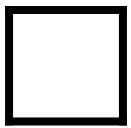
MMCi Block 4

Matthew Engelhard

Lecture 1: what is a predictive model?



x, data/features for
a subject or patient

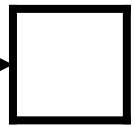


y, associated
value or label

End goal: predict y from x

-> Brief review

Lecture 2: a predictive model for image data



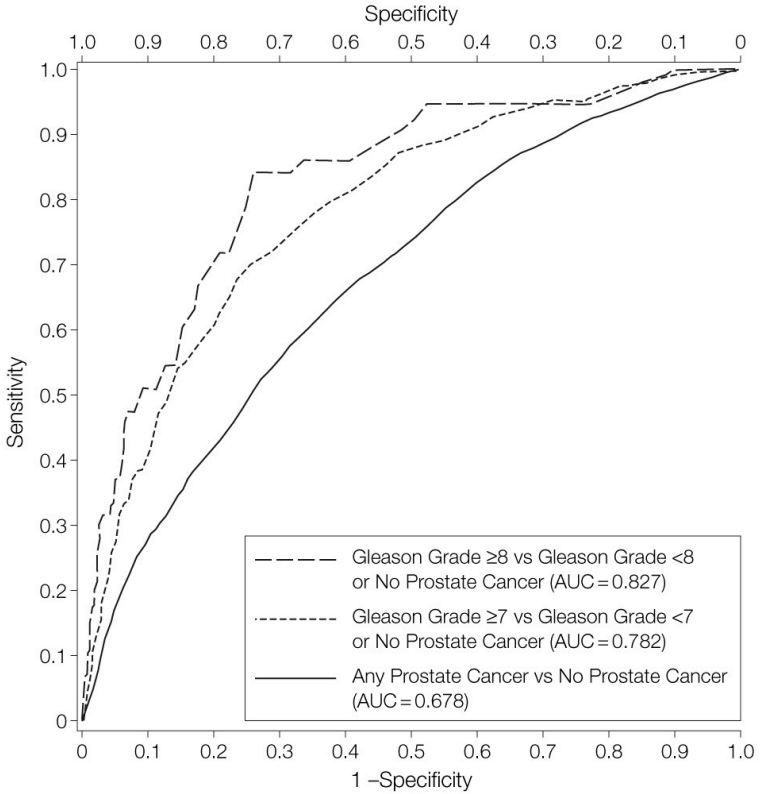
y, referrable diabetic retinopathy

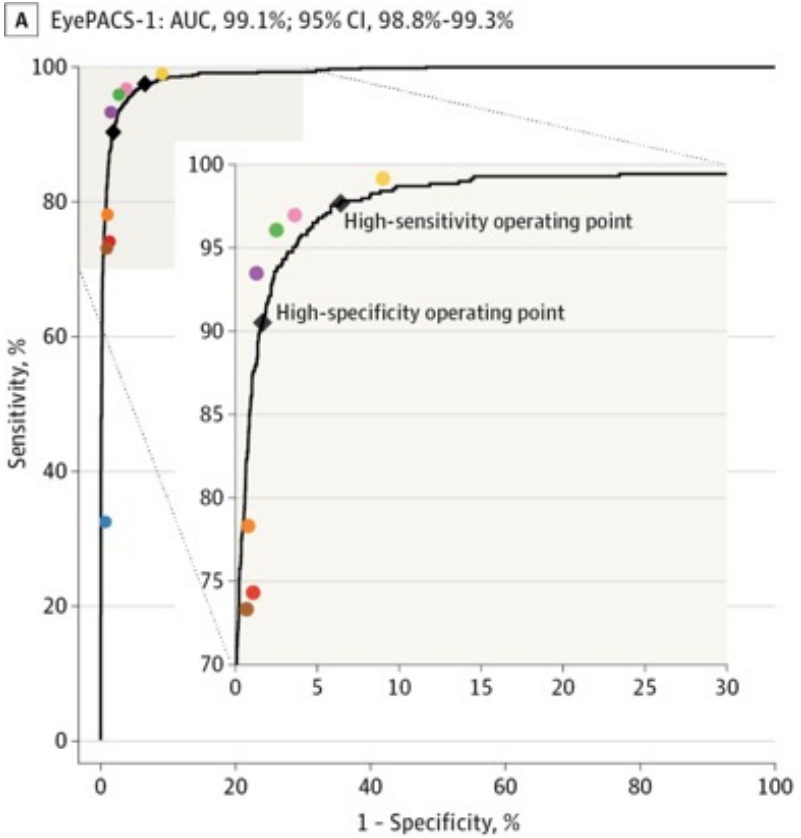
x, retinal image

End goal: predict *y* from *x*

-> Brief review

Evaluate performance just like any other diagnostic tool



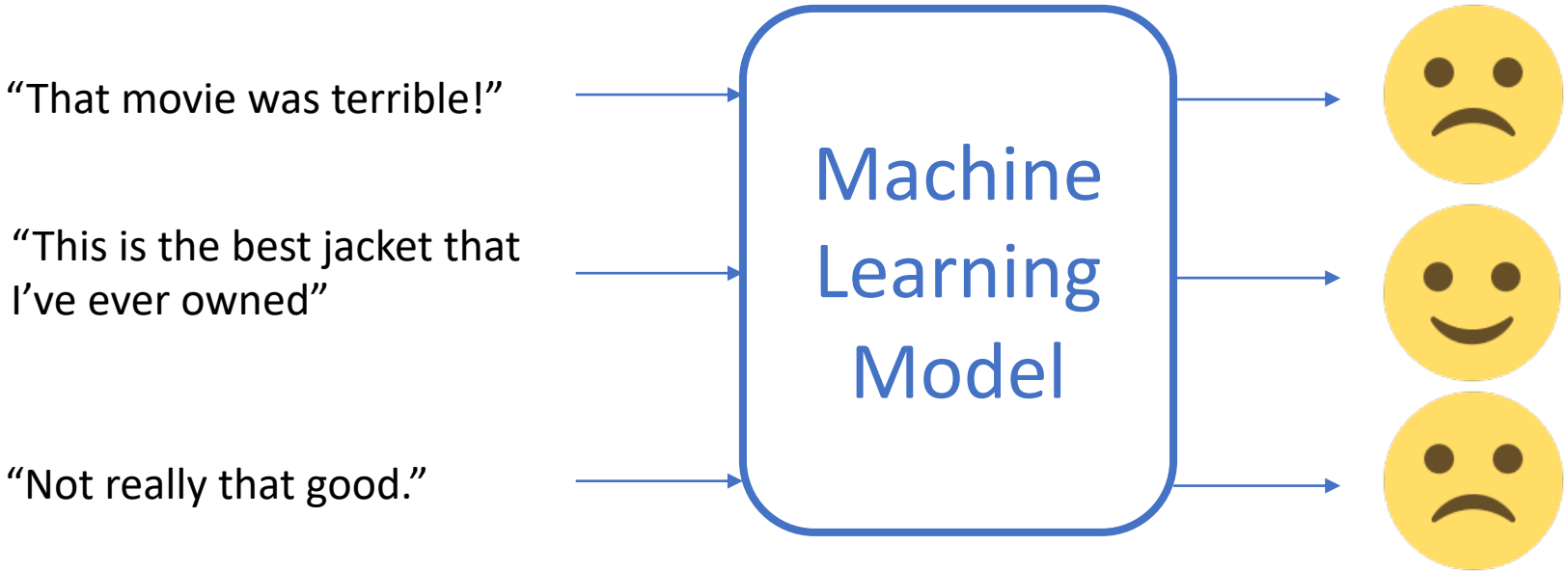


-> Brief review

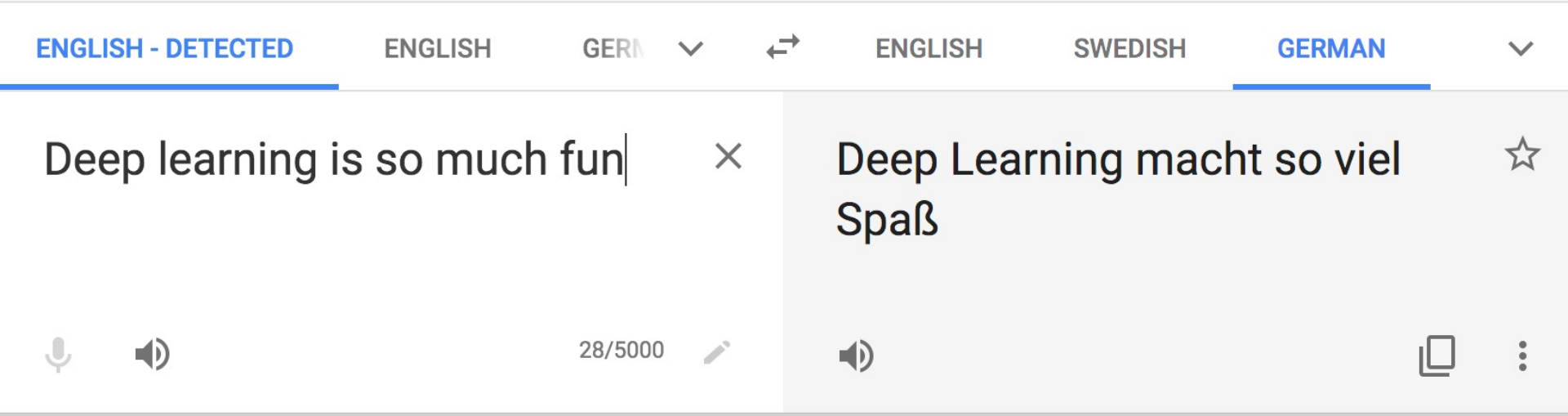
Today: a predictive model for text data

- What can “natural language processing” (NLP) do?
  - Existing non-medical applications
  - Possible medical applications
- How can we convert text into something a predictive model can understand?
- Evaluating and understanding NLP models

Sentiment Analysis:
An “easy” binary classification problem

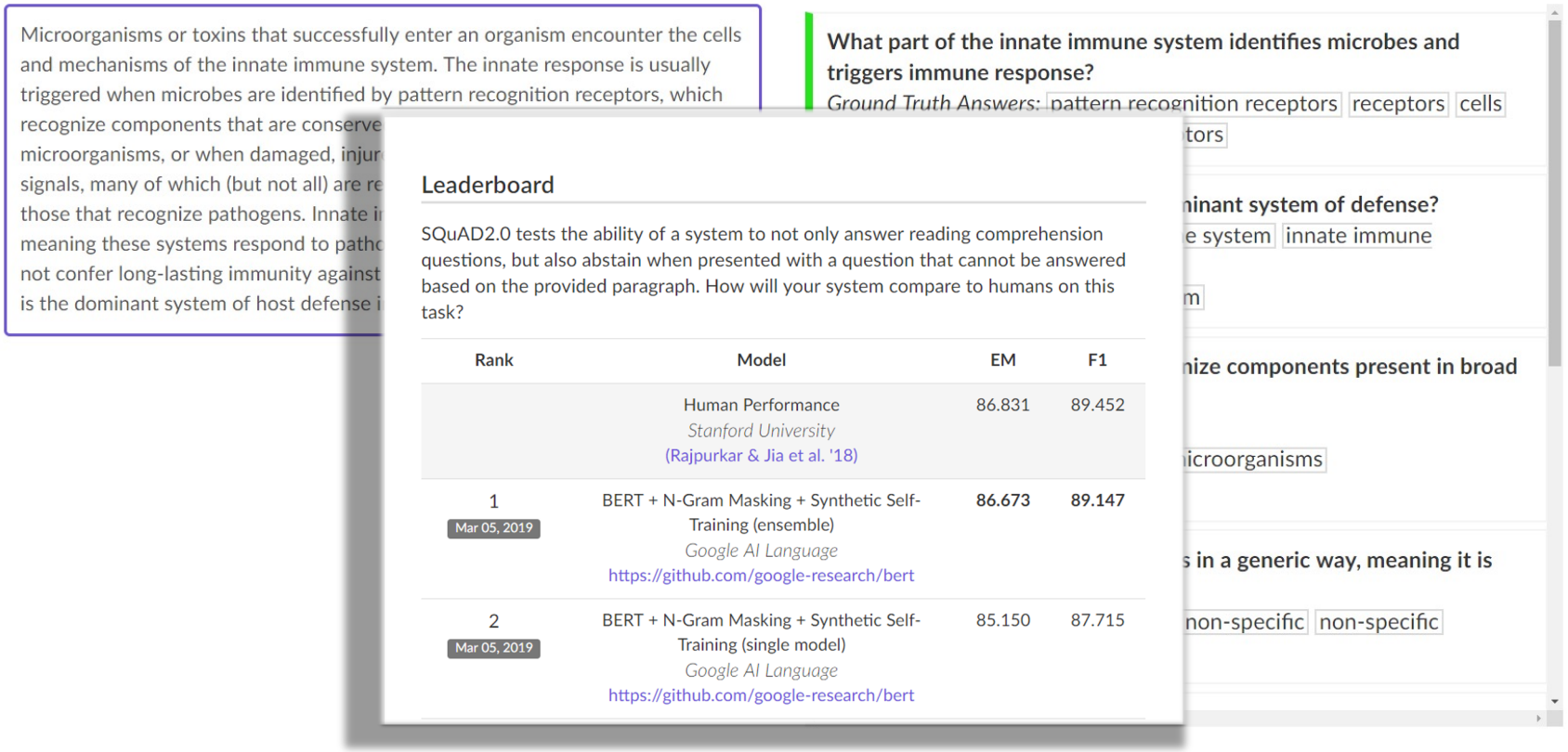


Text Translation



translate.google.com

Question Answering

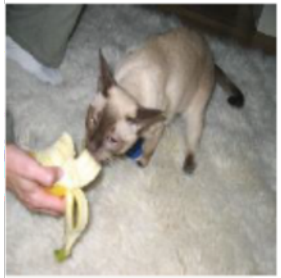


Automatic Image Captioning

a cow is standing in front of a store

a group of elephants standing next to each other

a table that has wooden spoons on it

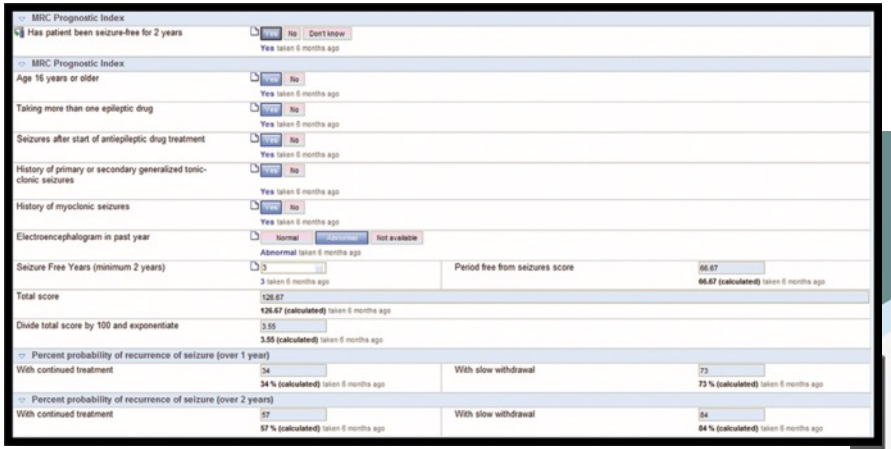


a cat is eating some kind of food

a bunch of bananas are sitting on a table

a motorcycle is parked next to a window

Populating Standardized Forms



Narayanan et al,
Epilepsia (2017)

Text Generation

SYSTEM PROMPT (HUMAN-WRITTEN)

A train carriage containing controlled nuclear materials was stolen in Cincinnati today. Its whereabouts are unknown.

MODEL COMPLETION (MACHINE-WRITTEN, FIRST TRY)

The incident occurred on the downtown train line, which runs from Covington and Ashland stations.

In an email to Ohio news outlets, the U.S. Department of Energy said it is working with the Federal Railroad Administration to find the thief.

“The theft of this nuclear material will have significant negative consequences on public and environmental health, our workforce and the economy of our nation,” said Tom Hicks, the U.S. Energy Secretary, in a statement. “Our top priority is to secure the theft and ensure it doesn’t happen again.”

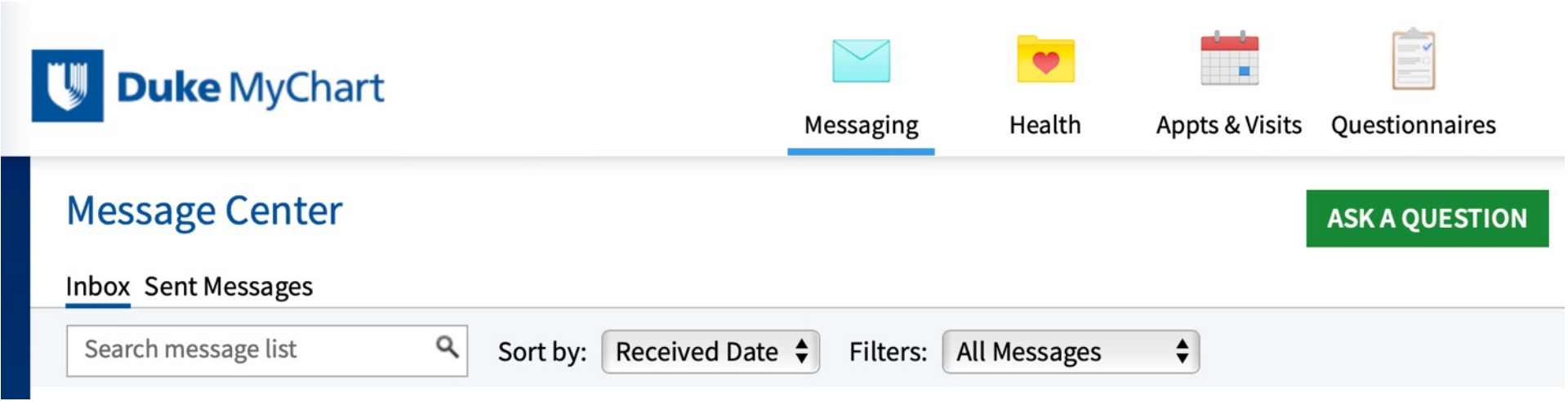
The stolen material was taken from the University of Cincinnati’s Research Triangle Park nuclear research site, according to a news release from Department officials.
The Nuclear Regulatory Commission did not immediately release any information.

According to the release, the U.S. Department of Energy’s Office of Nuclear Material Safety and Security is leading that team’s investigation.

“The safety of people, the environment and the nation’s nuclear stockpile is our highest priority,” Hicks said. “We will get to the bottom of this and make no excuses.

“Better Language Models and Their Implications”
2/14/19
OPENAI

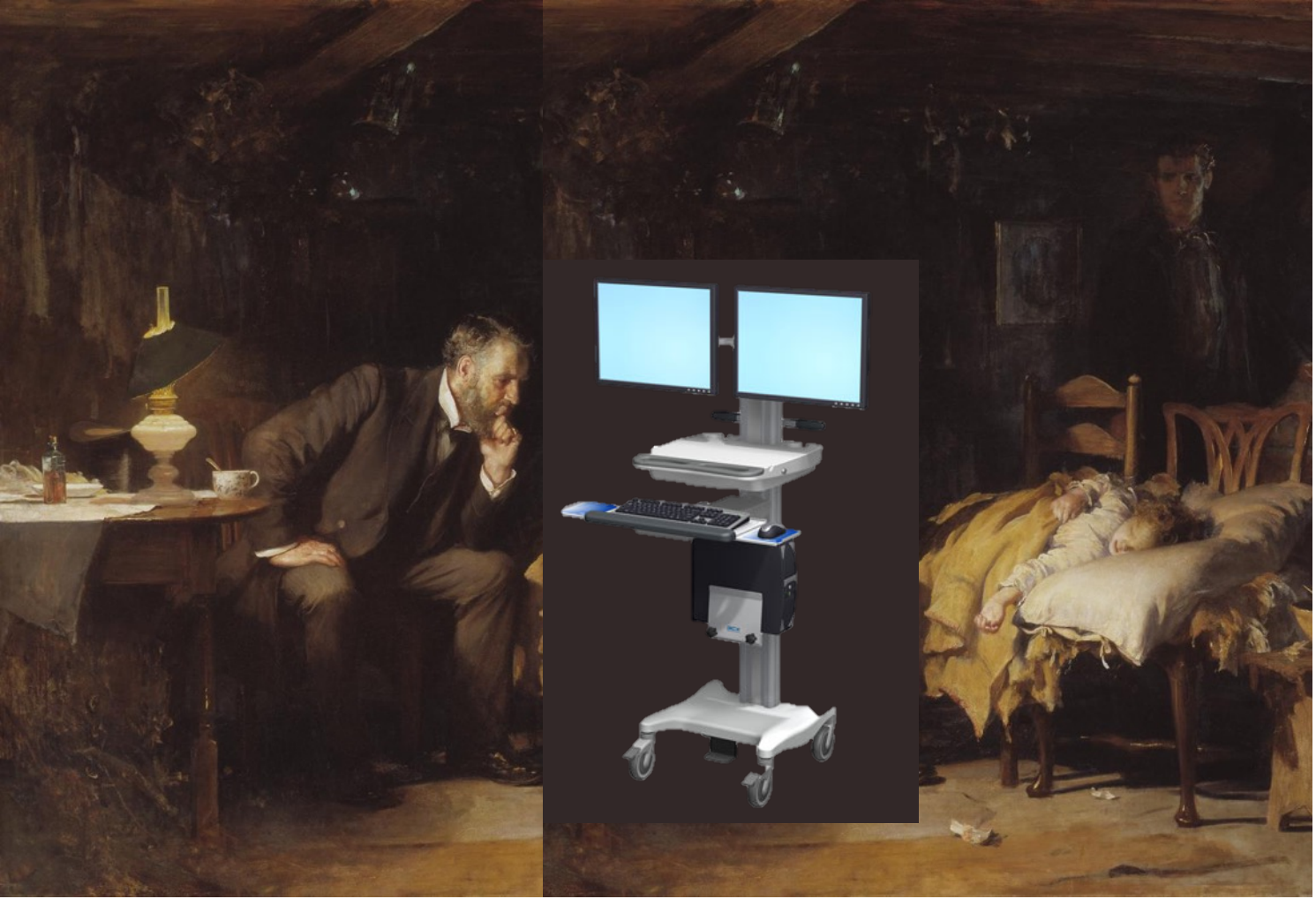
Suggested Email Responses



The Doctor

(Luke Fildes, 1891)

Inspired by MLHC keynote by Abraham Verghese, MD, MACP, Stanford University



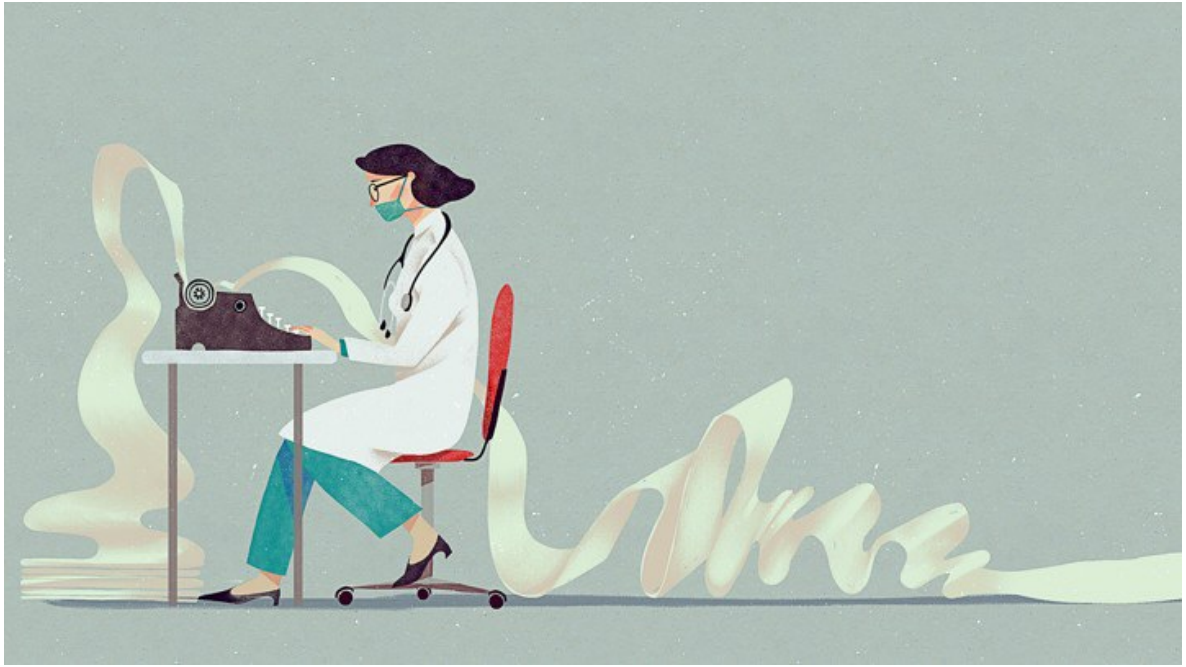
The Doctor,

circa 2018

Inspired by MLHC keynote by Abraham Verghese, MD, MACP, Stanford University

Reducing Burden and Restoring Patient-Provider Interaction

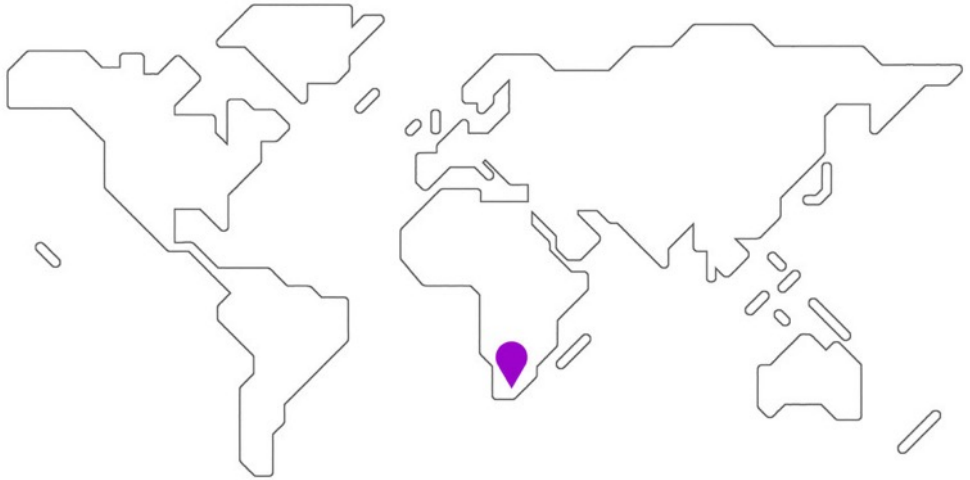
The Burnout Crisis in American Medicine
Rena Xu
The Atlantic
May 11, 2018



Case Study: SMS Triage for Global Maternal Health

Maternal Health HelpDesk:

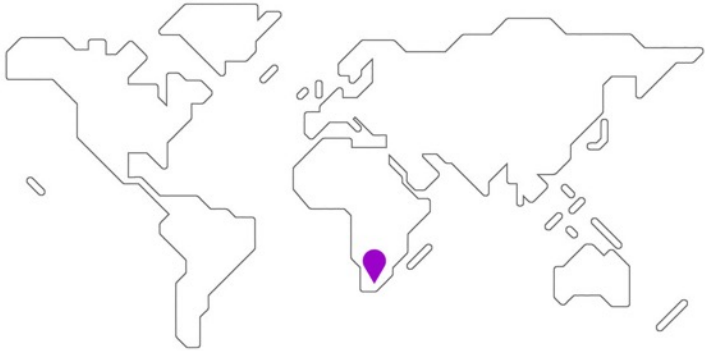
2 million women connected to NDoH staff via SMS



https://www.praekelt.org

Binary Classification: Urgent Message? (Yes/No)

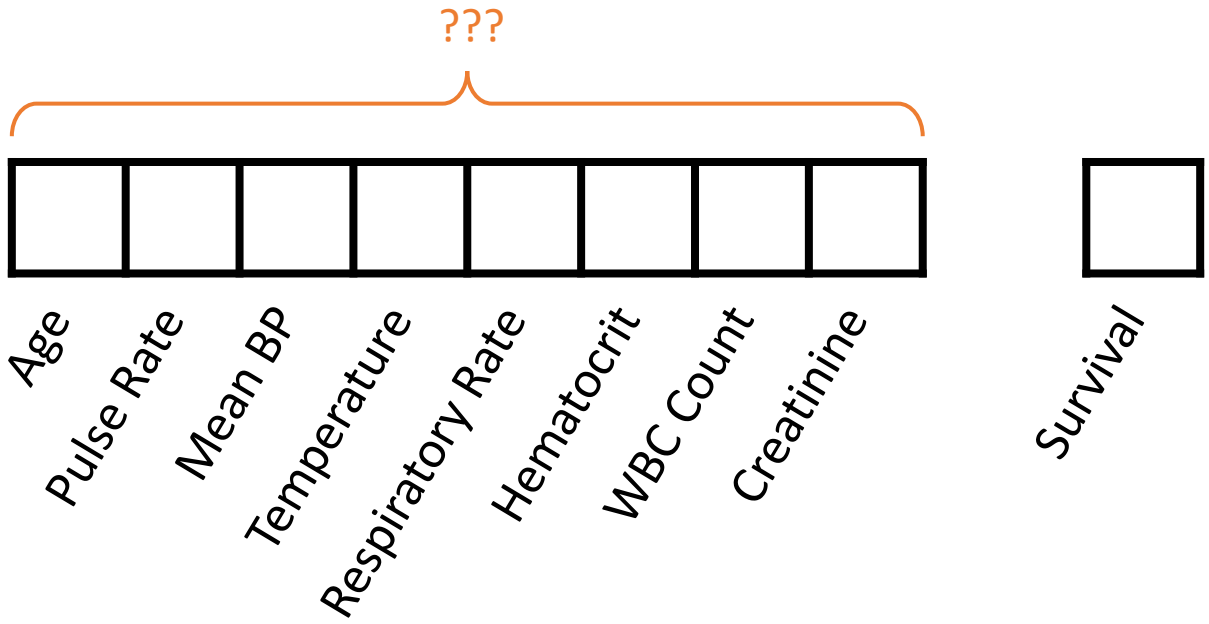
Case Study: SMS Triage for Global Maternal Health



https://www.praekelt.org

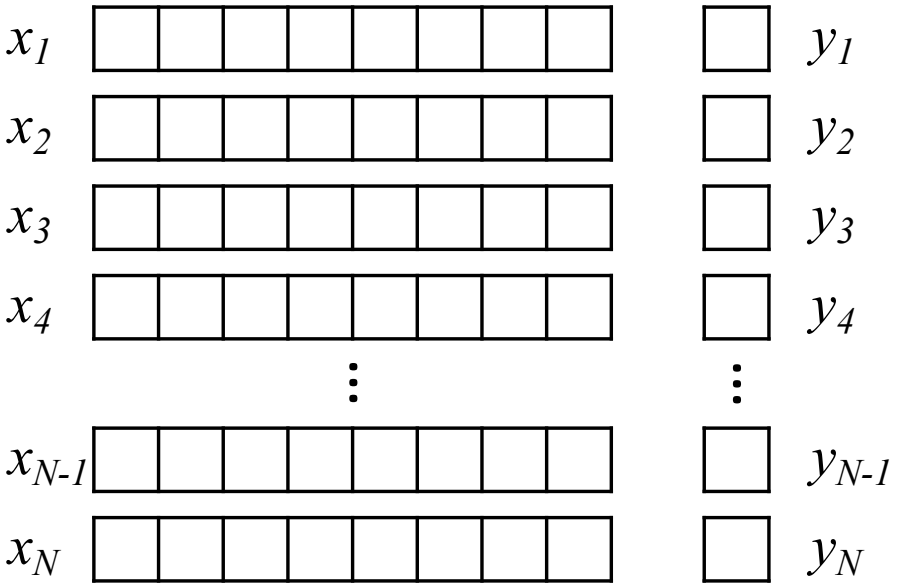
Can we use a standard predictive model setup to solve this problem?

A Simple Predictive Model: ICU Mortality



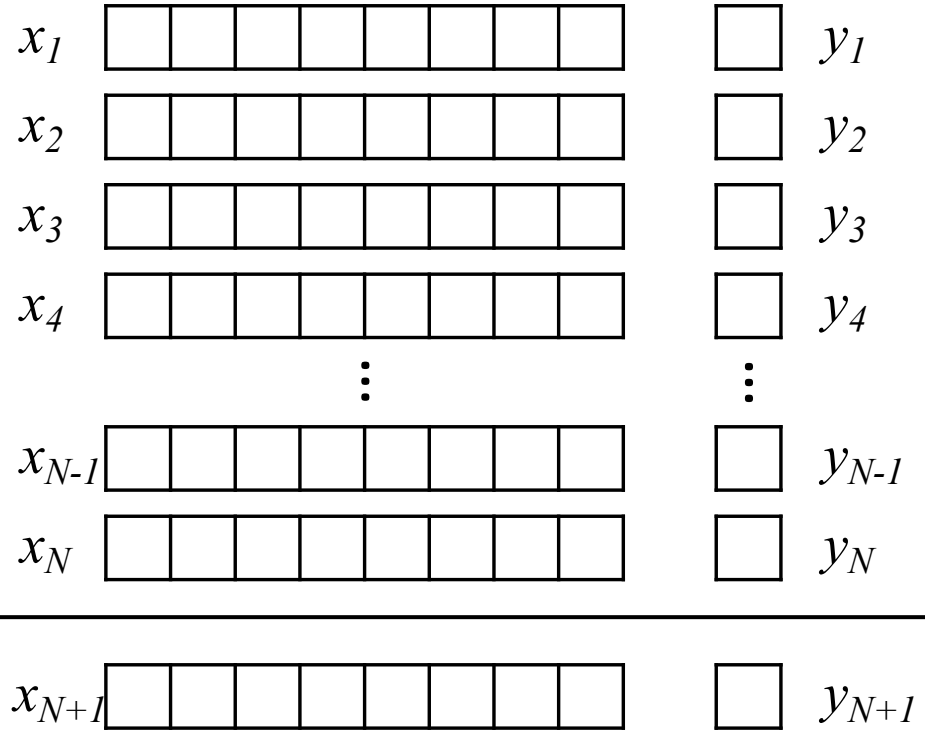
End goal: predict odds of hospital mortality

Training Set (Historical Data)



Find an equation that predicts y based on x across the training set

Making Predictions for New x



Find an equation that predicts y based on x across the training set

<- Learn to predict new y

This time, our training data is text

x_1	What helps with morning sickness?	☐	y_1
x_2	How many months should I breastfeed?	☐	y_2
x_3	I passed out and Mom said I was shaking	☐	y_3
x_4	Where is the nearest clinic?	☐	y_4
⋮	⋮	⋮	⋮
x_{N-1}	I am having heavy bleeding, what should I do?	☐	y_{N-1}
x_N	What foods should I eat while pregnant?	☐	y_N

y_i: Urgent or Not Urgent?

---

x_{N+1}	My heart is racing and I can't catch my breath	☐	y_{N+1}

<- Learn to predict new y

We need numbers, not words

- **Can we convert our text to a vector or sequence of numbers?**

- If yes, we can use logistic regression (or any other predictive model)!

First try: count words in each SMS
Step 1: Define a **vocabulary** of words

x_1	What helps with morning sickness?
x_2	How many months should I breastfeed?
x_3	I passed out and Mom said I was shaking
x_4	Where is the nearest clinic?

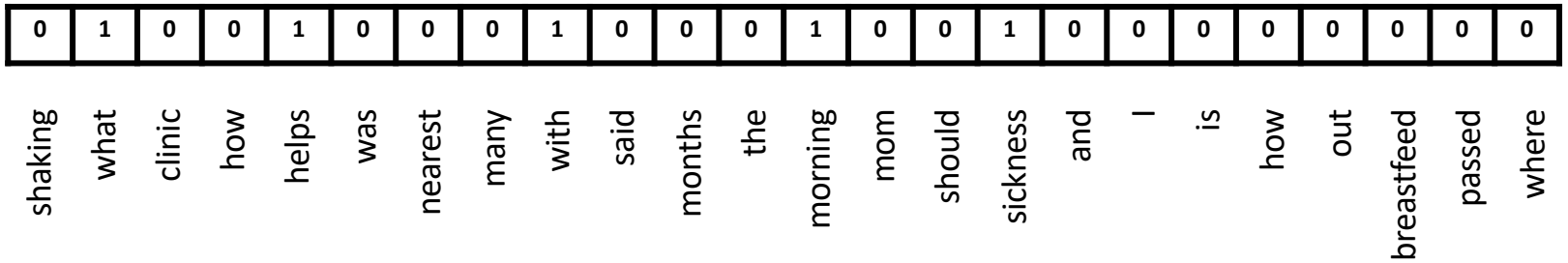
list of all words
(in no particular order)

shaking	with	and
what	said	I
clinic	months	is
how	the	how
helps	morning	out
was	mom	breastfeed
nearest	should	passed
many	sickness	where

Step 2: count how many times each vocabulary word appears in a given SMS

What helps with morning sickness?

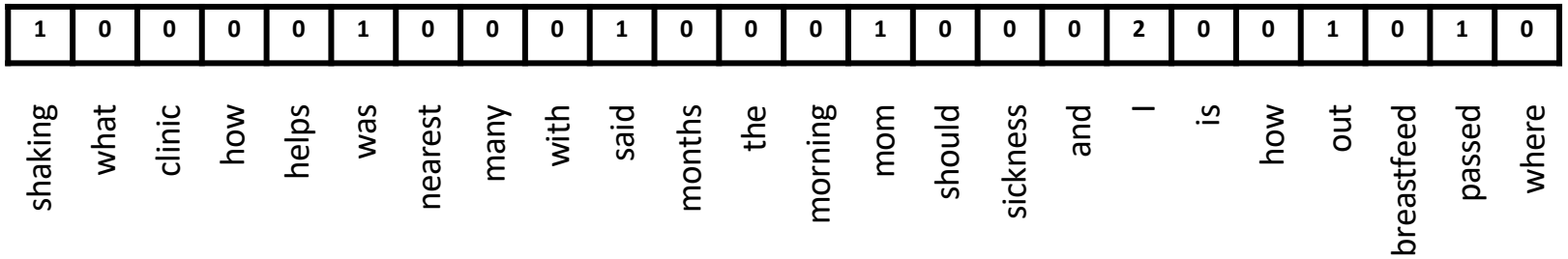
x_1



Step 2: count how many times each vocabulary word appears in a given SMS

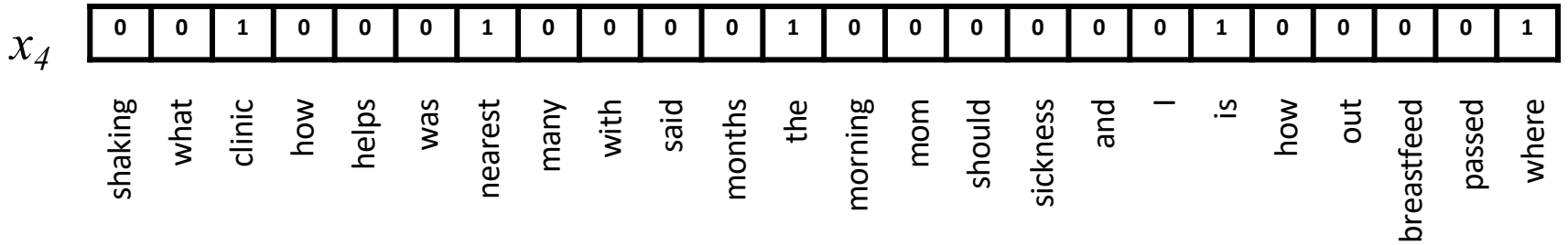
I passed out and Mom said I was shaking

x_3



Step 2: count how many times each vocabulary word appears in a given SMS

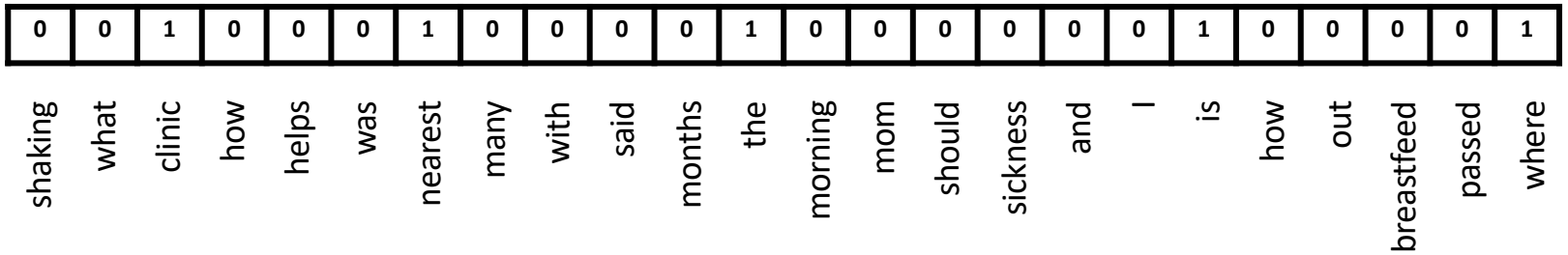
Where is the nearest clinic?



Note that word order does not matter!

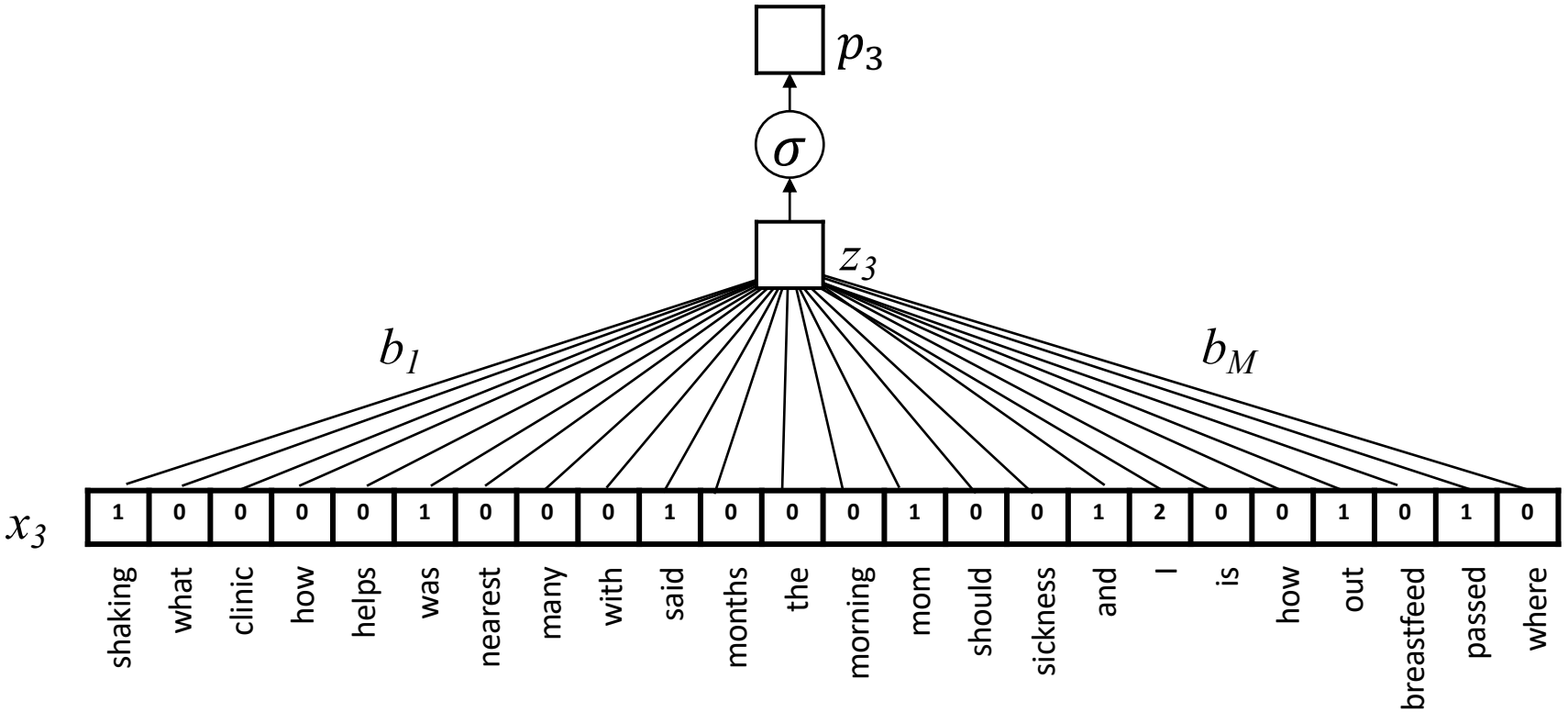
clinic is where nearest the

x_4 =



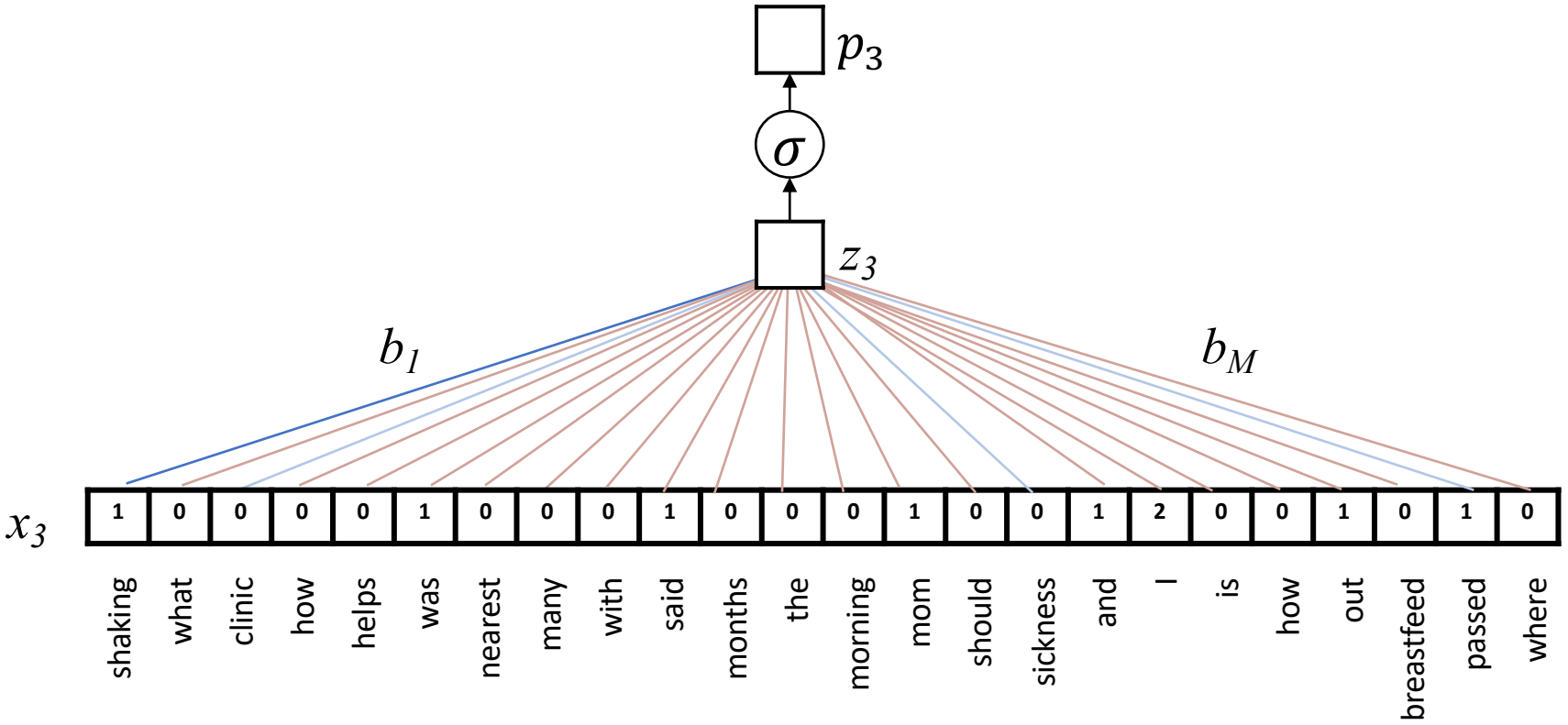
A “bag of words”

Logistic Regression for Text Classification



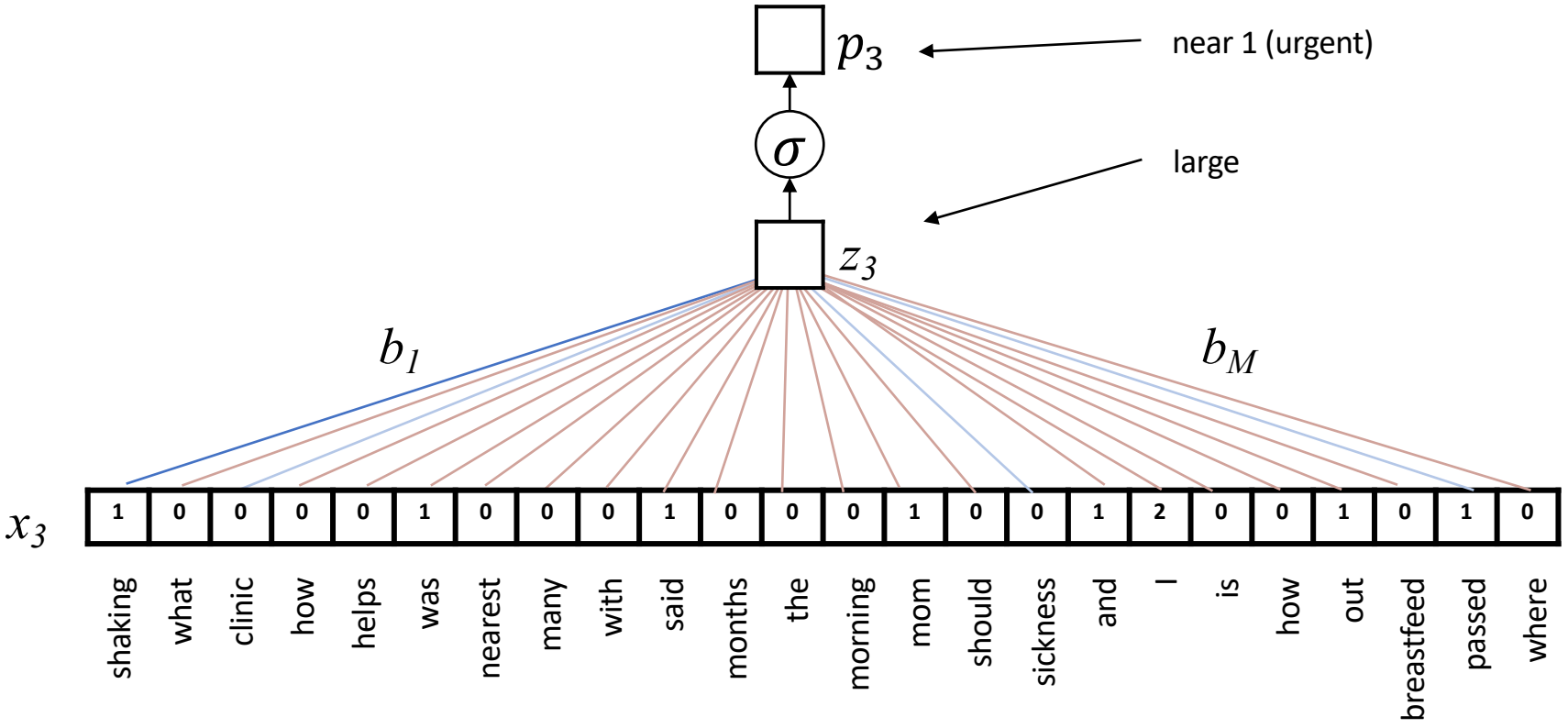
I passed out and Mom said I was shaking

Logistic Regression for Text Classification



I passed out and Mom said I was shaking

Logistic Regression for Text Classification



I passed out and Mom said I was shaking

Strengths and Weaknesses

- (+) This approach is simple and works surprisingly well in practice
- (+) Often the best approach with small datasets
- (-) Does not capture word order
- (-) Does not group synonyms together or understand semantic relationships between words

2nd try: count 1- and 2-grams in each SMS (i.e. extend vocabulary to include 2-word phrases)

x_1	What helps with morning sickness?
x_2	How many months should I breastfeed?
x_3	I passed out and Mom said I was shaking
x_4	Where is the nearest clinic?

1-grams

shaking	was	months	sickness	out
what	nearest	the	and	breastfeed
clinic	many	morning	I	passed
how	with	mom	is	where
helps	said	should	how	

2-grams

what helps	should I	said I
helps with	I breastfeed	I was
with morning	I passed	was shaking
morning sickness	passed out	where is
how many	out and	is the
many months	and mom	the nearest
months should	mom said	nearest clinic

n-grams can be very helpful!

I am not sick and feel great

I am not great and feel sick

Bag of 1-grams: no difference between these sentences

n-grams can be very helpful!

I am not sick and feel great

I am not great and feel sick

Bag of 1- and 2-grams:

not sick, **feel great**

versus

not great, **feel sick**

3rd try: more powerful methods to work with…

- (a) word meaning: assign words to vectors that encode their meaning numerically

- (b) words in context: neural network architectures that act on *sequences* of words (rather than a bag of words)

More Text Processing Details

(for bag of words models)

Variations on counting: term frequency

term count: ‘times’

2

“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way—in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.”

1

“And the first one now
Will later be last
For the times they are a-changin'.”

Variations on counting: term frequency

term frequency: ‘times’

2/119

“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way—in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.”

1/16

“And the first one now
Will later be last
For the times they are a-changin'.”

-> better measure of the importance of the term within a given text sample

Variations on counting: inverse document frequency

2/2

document frequency: ‘times’

✓ “It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way—in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.”

✓ “And the first one now
Will later be last
For the times they are a-changin'.”

Variations on counting: inverse document frequency

1/2

document frequency: ‘evil’

✓

“It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity, it was the season of Light, it was the season of Darkness, it was the spring of hope, it was the winter of despair, we had everything before us, we had nothing before us, we were all going direct to Heaven, we were all going direct the other way—in short, the period was so far like the present period, that some of its noisiest authorities insisted on its being received, for good or for evil, in the superlative degree of comparison only.”

✗

“And the first one now
Will later be last
For the times they are a-changin'.”

term frequency-inverse document frequency (tf-idf)

- What helps with morning sickness?
- How many months should I breastfeed?
- I passed out and Mom said I was shaking
- Where is the nearest clinic?
- I am having heavy bleeding, what should I do?
- What foods should I eat while pregnant?
- My heart is racing and I can't catch my breath

$$\frac{\text{term frequency}}{\text{document frequency}}$$ for 'shaking'

$$\frac{1/9}{1/7} = .78$$

$$\frac{\text{term frequency}}{\text{document frequency}}$$ for 'I'

$$\frac{2/9}{5/7} = .31$$

Preprocessing

- remove punctuation
- to lowercase
- “tokenization”
- “stemming”

```
I passed out, and Mom said I was shaking.

I passed out and Mom said I was shaking

i passed out and mom said i was shaking

[i, passed, out, and, mom, said, i, was, shaking]

[i, pass, out, and, mom, said, i, wa, shake]
```