Sequence Models

Introduction to
Artificial Intelligence
COS302
Michael L. Littman
Fall 2001

Administration

Exams enjoyed Toronto.
Letter grades for programs:
A: 74-100 (31)
B: 30-60 (20)
C: 10-15 (4)
?: (7)
(0 did not imply "incorrect")

Shannon Game

Sue swallowed the large green __.

pepper	frog
pea	pill

Not:

idea	beige
running	very

"AI Complete" Problem

My mom told me that playing Monopoly® with toddlers was a bad idea, but I thought it would be ok. I was wrong. Billy chewed on the "Get Out of Jail Free Card". Todd ran away with the little metal dog. Sue swallowed the large green __.

Language Modeling

- If we had a way of assigning probabilities to sentences, we could solve this. How?
- Pr(Sue swallowed the large green cat.)
- Pr(Sue swallowed the large green odd.)
- How could such a thing be learned from data?

Why Play This Game?

- Being able to assign likelihood to sentences a useful way of processing language.
- Speech recognition
- Criterion for comparing language models
- Techniques useful for other problems

Statistical Estimation

To use statistical estimation:

- Divide data into equivalence classes
- Estimate parameters for the different classes

Conflicting Interests

Reliability

- Lots of data in each class
- So, small number of classes

Discrimination

- All relevant distinctions made
- So, large number of classes

End Points

Unigram model:

Pr(w | Sue swallowed the large green ___.) = Pr(w)

Exact match model:

Pr(w | Sue swallowed the large green ___.) = Pr(w | Sue swallowed the large green ___.)

What word would these suggest?

N-grams: Compromise

N-grams are simple, powerful.

Bigram model:

Pr(w | Sue swallowed the large green ___.) = Pr(w | green ___)

Trigram model:

Pr(w | Sue swallowed the large green ___.) = Pr(w | large green ___)

Not perfect: misses "swallowed".

pillow	crystal	catepillar
Iguana	Santa	tigers

Aside: Syntax

Can do better with a little bit of knowledge about grammar:

Pr(w | Sue swallowed the large green ___.) = Pr(w | modified by swallowed, the, green)

pill	dye
one	pineapple
dragon	beans
speck	liquid
solution	drink

Estimating Trigrams

Treat sentences independently. Ok?

$Pr(w_1\ w_2)$

$Pr(w_j \mid w_{j-1}\ w_{j-2})$

$Pr(EOS \mid w_{j-1}\ w_{j-2})$

Simple so far.

Sparsity

Pr(w| comes across)

as	8/10 (in Austen's works)
a	1/10
more	1/10
the	0/10

Don't estimate as zeros!

Can use Laplace smoothing, e.g., or back off to bigram, unigram.

Unreliable Words

Can't take much stock in words only seen once (*hapax legomena*). Change to "UNK".

Generally a small fraction of the tokens and half the types.

The boy saw the dog.

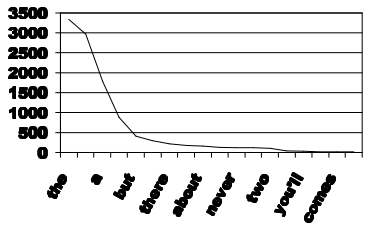
5 tokens, 4 types.

Zipf's Law

Frequency is proportional to rank.

Thus, extremely long tail!

Word Frequencies in Tom Sawyer



Using Trigrams

Hand me the ___ knife now .

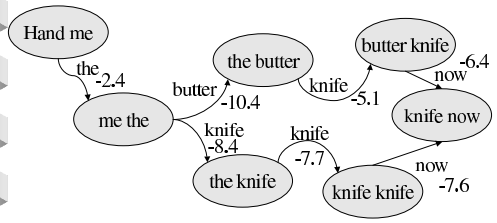
butter

knife

Counts

me the	2832670
me the butter	88
me the knife	638
the knife	154771
the knife knife	72
the butter	92304
the butter knife	559
knife knife	7831
knife knife now	4
butter knife	9046
butter knife now	15

Markov Model



General Scheme

$Pr(w_j = x \mid w_1\ w_2 \ldots EOS)$
$= Pr(w_1\ w_2 \ldots x \ldots EOS)$
$/ \text{ sum x } Pr(w_1\ w_2 \ldots x \ldots EOS)$
Maximized by $Pr(w_1\ w_2 \ldots x \ldots EOS)$
$= Pr(w_1\ w_2) \ldots Pr(x \mid w_{j-1}\ w_{j-2})$
$Pr(w_{j+1} \mid w_{j-1}\ x)\ Pr(w_{j+2} \mid x\ w_{j+1}) \ldots$
$Pr(\ EOS \mid w_{n-1}\ w_n)$
Maximized by $Pr(x \mid w_{j-1}\ w_{j-2})$
$Pr(w_{j+1} \mid w_{j-1}\ x)\ Pr(w_{j+2} \mid x\ w_{j+1})$

Mutual Information

- Log(Pr(x and y)/Pr(x) Pr(y))
- Measures the degree to which two events are independent (how much "information" we learn about one from knowing the other).

Mutual Inf. Application

- Measure of strength of association between words
- levied: imposed vs. believed
- Reduces to simply
- Pr(levied|x) = Pr(levied, x)/Pr(x)
  =count(levied and x) / count (x)
- "imposed" has higher score.

Analogy Idea

- Find a linking word such that a mutual information score is maximized.
- Tricky to find the right word. Unclear if any word will have the right effect.
- traffic flows through the street
  water flows through the riverbed

What to Learn

- Reliability/discrimination tradeoff.
- Definition of N-gram models
- How to find most likely word in an N-gram model
- Mutual Information

Homework 7 (due 11/21)

1. Give a maximization scheme for filling in the two blanks in a sentence like "I hate it when ___ goes ___ on me." Be somewhat rigorous to make the TA's job easier.
2. more soon