

## Grouping Words

PA154 Language Modeling (7.1)

Pavel Rychlý

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March 30, 2023

Source: Natural Language Processing (600.465)  
Jason Eisner, Johns Hopkins Univ.  
www.cs.jhu.edu/~jason/465/

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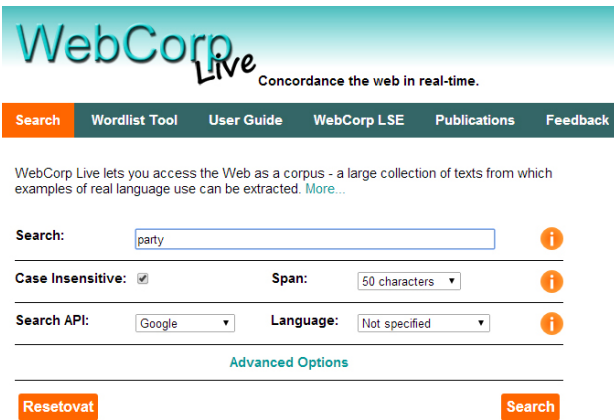
## Linguistic Objects in this Course

- **Trees (with strings at the nodes)**
  - Syntax, semantics
  - Algorithms: *Generation, parsing, inside-outside, build semantics*
- **Sequences (of strings)**
  - n-grams, tag sequences
  - morpheme sequences, phoneme sequences
  - Algorithms: *Finite-state, best-paths, forward-backward*
- **"Atoms" (unanalyzed strings)**
  - Words, morphemes
  - Represent by contexts – other words they occur with
  - Algorithms: **Grouping similar words, splitting words into senses**

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## A Concordance for "party" - from www.webcorp.org.uk



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- thing. She was talking at a **party** thrown at Daphne's restaurant in
- have turned it into the hot dinner-**party** topic. The comedy is the
- selection for the World Cup **party**, which will be announced on May 1
- in the 1983 general election for a **party** which, when it could not bear to
- to attack the Scottish National **Party**, who look set to seize Perth and
- that had been passed to a second **party** who made a financial decision
- the by-pass there will be a street **party**. "Then," he says, "we are going
- number-crunchers within the Labour **party**, there now seems little doubt
- political tradition and the same **party**. They are both relatively Anglophilic
- he told Tony Blair's modernised **party** they must not retreat into "warm
- "Oh no, I'm just here for the **party**," they said. "I think it's terrible
- A future obliges each **party** to the contract to fulfil it by
- be signed by or on behalf of each **party** to the contract." Mr David N

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## What Good are Word Senses?

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## What Good are Word Senses?

John threw a "rain forest" party last December. His living room was full of plants and his box was playing Brazilian music ...

## What Good are Word Senses?

- Replace word **w** with sense **s**
  1. *Splits w* into senses: distinguishes this token of **w** from tokens with sense **t**
  2. *Groups w* with other words: groups this token of **w** with tokens of **x** that also have sense **s**

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- an appearance at the annual awards **bash** , but feels in no fit state to
- -known families at a fundraising **bash** on Thursday night for Learning
- Who was paying for the **bash**? The only clue was the name Asprey,
- Mail, always hosted the annual **bash** for the Scottish Labour front-
- popular. Their method is to **bash** sense into criminals with a short,
- just cut off people's heads and **bash** their brains out over the floor,

## What Good are Word Senses?

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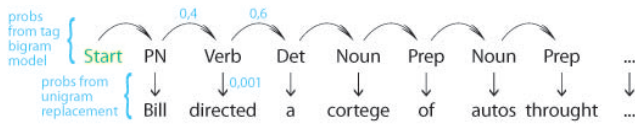
- **Semantics / Text understanding**
  - Axioms about TRANSFER apply to (some tokens of) throw
  - Axioms about BUILDING apply to (some tokens of) bank
- **Machine translation**
- **Info retrieval / Question answering / Text categ.**
  - Query or pattern might not match document exactly
- **Backoff for just about anything**
  - what word comes next? (speech recognition, language ID,...)
    - trigrams are sparse but tri-meanings might not be
  - bilexical PCFGs:
    - $p(S[\text{devour}] \rightarrow NP[\text{lion}] VP[\text{devour}] | S[\text{devour}])$
    - approximate by  $p(S[\text{EAT}] \rightarrow NP[\text{lion}] VP[\text{EAT}] | S[\text{EAT}])$
- **Speaker's real intention is senses; words are a noisy channel**

## Cues to Word Sense

- Adjacent words (or their senses)
- Grammatically related words (subject, object, ...)
- Other nearby words
- Topic of document
- Sense of other tokens of the word in the same document

## Word Classes by Tagging

- Every tag is a kind of class
- Tagger assigns a class to each word token



## Word Classes by Tagging

- Every tag is a kind of class
- Tagger assigns a class to each word token
  - Simultaneously groups and splits words
  - “party” gets split into N and V senses
  - “bash” gets split into N and V senses
  - {party/N, bash/N} vs. {party/V, bash/V}
  - What good are these groupings?

## Learning Word Classes

- Every tag is a kind of class
- Tagger assigns a class to each word token
  - {party/N, bash/N} vs. {party/V, bash/V}
  - What good are these groupings?
  - Good for predicting next word or its class!
- Role of forward-backward algorithm?
  - It adjusts classes etc. in order to predict sequence of words better (with lower perplexity)

## Words and Vectors

- Represent each word **type**  $w$  (party) by a point in  $k$ -dimensional space
  - e.g.,  $k$  is size of vocabulary
  - the  $17^{\text{th}}$  coordinate of  $w$  represents **strength** of  $w$ 's association with vocabulary word 17

Word	Count	
aardvark	0	
abacus	0	
abandoned	3	
abbot	1	
abduct	0	
above	7	too high
zygote	1	
zymurgy	0	too low

From corpus:

Jim Jeffords **abandoned** the Republican **party**.  
 There were lots of **abbots** and nuns dancing at that **party**.  
 The **party above** the art gallery was, **above** all, a laboratory for synthesizing **zygotes** and beer.

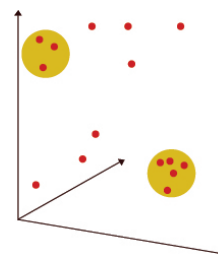
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  - the  $17^{\text{th}}$  coordinate of  $w$  represents **strength of  $w$ 's association** with vocabulary word 17.
- *How might you measure this?*
  - how often words appear next to each other
  - how often words appear near each other
  - how often words are syntactically linked
  - should correct for commonness of word (e.g., “above”)

- Represent **each word type  $w$  (party)** by a point in  $k$ -dimensional space
  - e.g.,  $k$  is size of vocabulary
  - the 17th coordinate of  $w$  represents **strength** of  $w$ 's association with vocabulary word 17.
- Plot all word types in  $k$ -dimensional space
- Look for **clusters** of close-together types

## Learning Classes by Clustering

- Plot all word types in  $k$ -dimensional space
- Look for **clusters** of close-together types

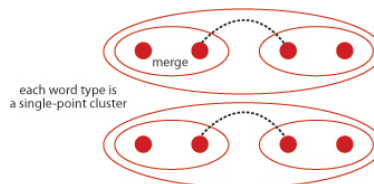
Plot in  $k$  dimensions ( $k=3$ )



## Bottom-Up Clustering

- Start with one cluster per point
- Repeatedly merge 2 closest clusters
  - **Single-link:**  $\text{dist}(A,B) = \min \text{dist}(a,b)$  for  $a \in A, b \in B$
  - **Complete-link:**  $\text{dist}(A,B) = \max \text{dist}(a,b)$  for  $a \in A, b \in B$

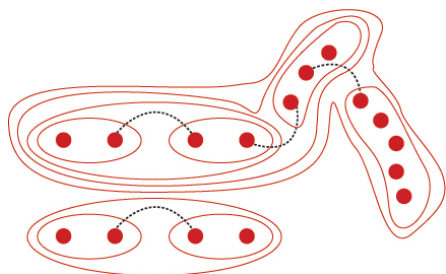
## Single-Link



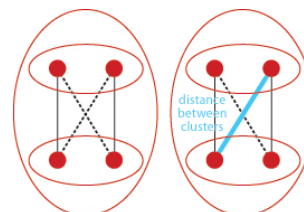
- Again, merge closest pair of clusters:
  - **Single-link:** clusters are close if any of their points are  $\text{dist}(A,B) = \min \text{dist}(a,b)$  for  $a \in A, b \in B$

## Single-Link

- Fast, but tend to get long, stringy, meandering clusters



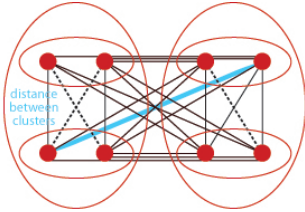
## Complete-Link



- Again, merge closest pair of clusters:
  - **Complete-link:** clusters are close only if **all** of their points are  $\text{dist}(A,B) = \max \text{dist}(a,b)$  for  $a \in A, b \in B$

## Complete-Link

- Slow to find closest pair – need quadratically many distances



## Summary

- Start with one cluster per point
- Repeatedly merge 2 closest clusters
  - **Single-link:**  $\text{dist}(A,B) = \min \text{dist}(a,b)$  for  $a \in A, b \in B$
  - **Complete-link:**  $\text{dist}(A,B) = \max \text{dist}(a,b)$  for  $a \in A, b \in B$ 
    - too slow to update cluster distances after each merge; but alternatives!
  - **Average-link:**  $\text{dist}(A,B) = \text{mean dist}(a,b)$  for  $a \in A, b \in B$
  - **Centroid-link:**  $\text{dist}(A,B) = \text{dist}(\text{mean}(A), \text{mean}(B))$
- Stop when clusters are “big enough”
  - e.g., provide adequate support for backoff (on a development corpus)
- Some flexibility in defining  $\text{dist}(a,b)$ 
  - Might not be Euclidean distance; e.g., use vector angle

## EM Clustering (for k clusters)

- **EM algorithm**
  - **Viterbi version** – called “k-means clustering”
  - **Full EM version** – called “Gaussian mixtures”
- **Expectation step:** Use current parameters (and observations) to reconstruct hidden structure
- **Maximization step:** Use that hidden structure (and observations) to reestimate parameters
- **Parameters:** k points representing cluster centers
- **Hidden structure:** for each data point (word type), which center generated it?