CS378: Natural Language Processing
Lecture 10: Seq 3 / Syntax I

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Announcements

- A2 due today
- A3 out tomorrow
- Midterm: list of topics next week. Covers content up to March 7
  - CRFs will NOT be on the midterm, a couple other topics too

Today

- Conditional random fields
- Named entity recognition
- Syntax and constituency parsing

CRFs and NER

Named Entity Recognition

B-PER I-PER O O O B-LOC O O O B-ORG O O

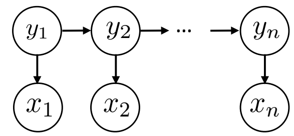
Barack Obama will travel to Hangzhou today for the G20 meeting .

PERSON LOC ORG

- Frame as a sequence problem with a BIO tagset: begin, inside, outside
- Why might an HMM not do so well here?
  - Lots of O's, so tags aren't as informative about context
  - Need sub-word features on unknown words
- CRFs are discriminative models that will solve these problems

Conditional Random Fields

- HMMs are expressible as Bayes nets (factor graphs)



- This reflects the following decomposition:

$$P(\mathbf{y}, \mathbf{x}) = P(y_1)P(x_1|y_1)P(y_2|y_1)P(x_2|y_2)\ldots$$

- Locally normalized model: each factor is a probability distribution that normalizes

Conditional Random Fields

- HMMs: $P(\mathbf{y}, \mathbf{x}) = P(y_1)P(x_1|y_1)P(y_2|y_1)P(x_2|y_2)\ldots$
- CRFs: discriminative models with the following globally-normalized form:

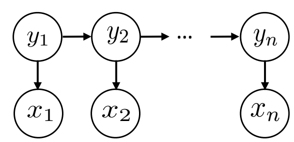
$$P(\mathbf{y}|\mathbf{x}) = \frac{\prod_k \exp(\phi_k(\mathbf{x}, \mathbf{y}))}{\underbrace{\sum_{\mathbf{y}'}}_{\text{normalizer } Z} \prod_k \exp(\phi_k(\mathbf{x}, \mathbf{y}'))}$$

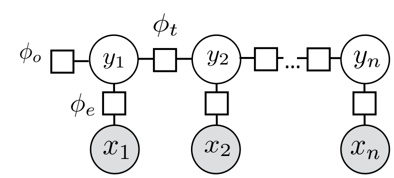
any real-valued scoring function of its arguments

- Naive Bayes : logistic regression :: HMMs : CRFs
  local vs. global normalization <-> generative vs. discriminative
- How do we max over ***y***? Requires considering an exponential number of sequences in general

Sequential CRFs

- HMMs: $P(\mathbf{y}, \mathbf{x}) = P(y_1)P(x_1|y_1)P(y_2|y_1)P(x_2|y_2)\ldots$



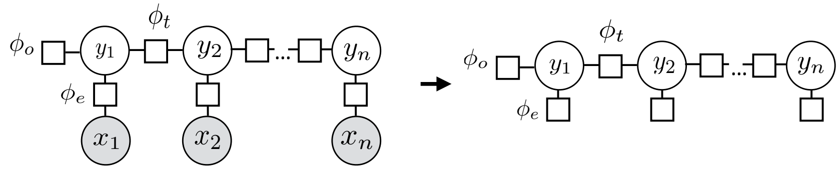


- CRFs:

$$P(\mathbf{y}|\mathbf{x}) \propto \prod_k \exp(\phi_k(\mathbf{x}, \mathbf{y}))$$

$$P(\mathbf{y}|\mathbf{x}) \propto \exp(\phi_o(y_1)) \prod_{i=2}^{n} \exp(\phi_t(y_{i-1}, y_i)) \prod_{i=1}^{n} \exp(\phi_e(x_i, y_i))$$

Sequential CRFs



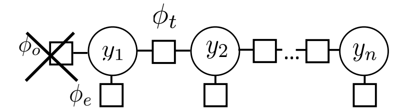
$$P(\mathbf{y}|\mathbf{x}) \propto \exp(\phi_o(y_1)) \prod_{i=2}^{n} \exp(\phi_t(y_{i-1}, y_i)) \prod_{i=1}^{n} \cancel{\exp(\phi_e(x_i, y_i))}$$

$$\prod_{i=1}^{n} \exp(\phi_e(y_i, i, \mathbf{x}))$$

token index — lets us look at current word

- We condition on **x**, so every factor can depend on all of **x**
- **y** can't depend arbitrarily on **x** in a generative model

Sequential CRFs



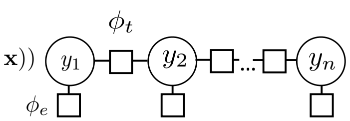
- Don't include initial distribution, can bake into other factors

Sequential CRFs:

$$P(\mathbf{y}|\mathbf{x}) = \frac{1}{Z} \prod_{i=2}^{n} \exp(\phi_t(y_{i-1}, y_i)) \prod_{i=1}^{n} \exp(\phi_e(y_i, i, \mathbf{x}))$$

Feature Functions

$$P(\mathbf{y}|\mathbf{x}) = \frac{1}{Z} \prod_{i=2}^{n} \exp(\phi_t(y_{i-1}, y_i)) \prod_{i=1}^{n} \exp(\phi_e(y_i, i, \mathbf{x}))$$



- Phis can be almost anything! Here we use linear functions of sparse features

$$\phi_e(y_i, i, \mathbf{x}) = w^\top f_e(y_i, i, \mathbf{x}) \qquad \phi_t(y_{i-1}, y_i) = w^\top f_t(y_{i-1}, y_i)$$

$$P(\mathbf{y}|\mathbf{x}) \propto \exp w^\top \left[\sum_{i=2}^{n} f_t(y_{i-1}, y_i) + \sum_{i=1}^{n} f_e(y_i, i, \mathbf{x}) \right]$$

- Looks like our single weight vector multiclass logistic regression model

Basic Features for NER

$$P(\mathbf{y}|\mathbf{x}) \propto \exp w^\top \left[\sum_{i=2}^{n} f_t(y_{i-1}, y_i) + \sum_{i=1}^{n} f_e(y_i, i, \mathbf{x}) \right]$$

O B-LOC

Barack Obama will travel to Hangzhou today for the G20 meeting .

Transitions: $f_t(y_{i-1}, y_i) = \mathrm{Ind}[y_{i-1} \ \& \ y_i]$ = Ind[O — B-LOC]

Emissions: $f_e(y_6, 6, \mathbf{x}) =$ Ind[B-LOC & Current word = *Hangzhou*]

Ind[B-LOC & Prev word = *to*]

CRFs Outline

- Model: $P(\mathbf{y}|\mathbf{x}) = \frac{1}{Z} \prod_{i=2}^{n} \exp(\phi_t(y_{i-1}, y_i)) \prod_{i=1}^{n} \exp(\phi_e(y_i, i, \mathbf{x}))$

$$P(\mathbf{y}|\mathbf{x}) \propto \exp w^\top \left[\sum_{i=2}^{n} f_t(y_{i-1}, y_i) + \sum_{i=1}^{n} f_e(y_i, i, \mathbf{x}) \right]$$

- Inference: argmax P(**y**|**x**) from Viterbi
- Learning: requires running sum-product Viterbi to compute posterior probabilities P(y | **x**) at each step *i*

Features for NER

- Word features (can use in HMM)
  - Capitalization
  - Word shape
  - Prefixes/suffixes
  - Lexical indicators
- Context features (can't use in HMM!)
  - Words before/after
  - Tags before/after
- Word clusters
- Gazetteers

Leicestershire

Boston

Apple released a new version…

According to the New York Times…

Evaluating NER

B-PER I-PER O O O B-LOC O O O B-ORG O O

Barack Obama will travel to Hangzhou today for the G20 meeting .

PERSON LOC ORG

- Prediction of all Os still gets 66% accuracy on this example!
- What we really want to know: how many named entity *chunk* predictions did we get right?
  - Precision: of the ones we predicted, how many are right?
  - Recall: of the gold named entities, how many did we find?
  - F-measure: harmonic mean of these two

NER

- CRF with lexical features can get around 85 F1 on this problem
- Other pieces of information that many systems capture
- World knowledge:

The delegation met the president at the airport, Tanjug said.

Tanjug

From Wikipedia, the free encyclopedia

Tanjug (/ˈtʌnjʊg/) (Serbian Cyrillic: Танјуг) is a Serbian state news agency based in Belgrade.[2]

Nonlocal Features

The news agency Tanjug reported on the outcome of the meeting.

ORG?

PER?

The delegation met the president at the airport, Tanjug said.

- More complex factor graph structures can let you capture this, or just decode sentences in order and use features on previous sentences

Finkel and Manning (2008), Ratinov and Roth (2009)

How well do NER systems do?

	System	Resources Used	F_1
+	LBJ-NER	Wikipedia, Nonlocal Features, Word-class Model	90.80
-	(Suzuki and Isozaki, 2008)	Semi-supervised on 1G-word unlabeled data	89.92
-	(Ando and Zhang, 2005)	Semi-supervised on 27M-word unlabeled data	89.31
-	(Kazama and Torisawa, 2007a)	Wikipedia	88.02
-	(Krishnan and Manning, 2006)	Non-local Features	87.24
-	(Kazama and Torisawa, 2007b)	Non-local Features	87.17
+	(Finkel et al., 2005)	Non-local Features	86.86

Ratinov and Roth (2009)

Lample et al. (2016)

LSTM-CRF (no char)	90.20
LSTM-CRF	**90.94**
S-LSTM (no char)	87.96
S-LSTM	90.33

BiLSTM-CRF + ELMo **92.2**

Peters et al. (2018)

Takeaways

- CRFs are structured feature-based models
- Efficient to do inference and learning using dynamic programs
- Looks like logistic regression, but requires more effort to implement

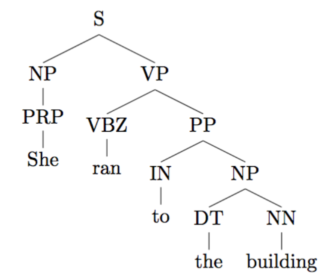
Constituency Parsing

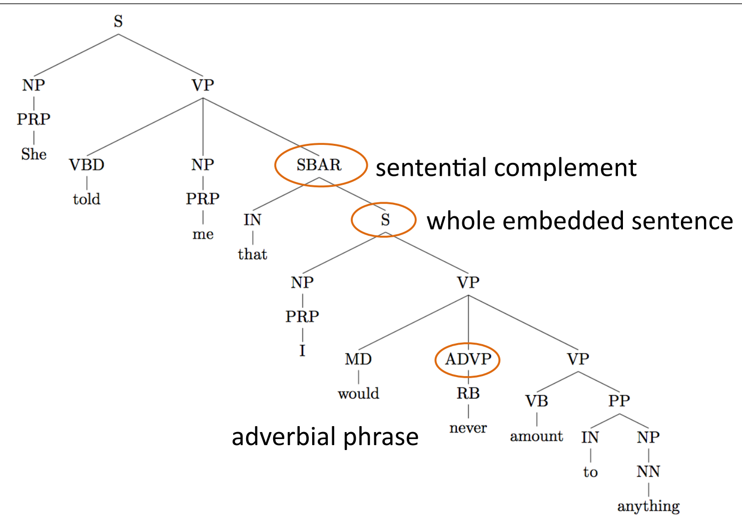
Syntax

- Study of word order and how words form sentences
- Why do we care about syntax?
  - Multiple interpretations of words (noun or verb? *Fed raises*… example)
  - Recognize verb-argument structures (who is doing what to whom?)
  - Higher level of abstraction beyond words: some languages are SVO, some are VSO, some are SOV, parsing can canonicalize

Constituency Parsing

- Tree-structured syntactic analyses of sentences
- Common things: noun phrases, verb phrases, prepositional phrases
- Bottom layer is POS tags
- Examples will be in English. Constituency makes sense for a lot of languages but not all



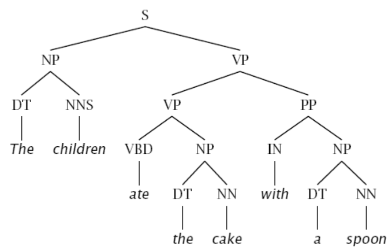


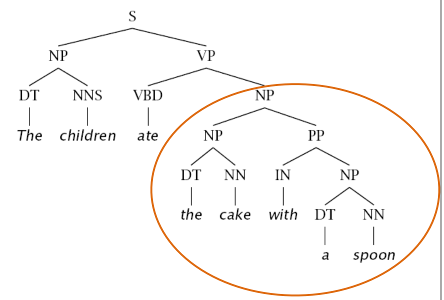
Constituency Parsing

Examples

Challenges

- PP attachment

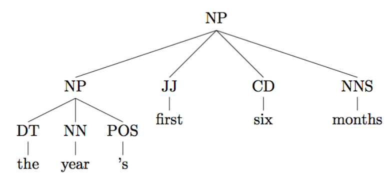


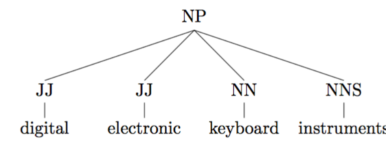


same parse as "the cake with some icing"

Challenges

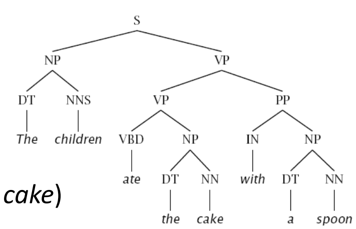
- NP internal structure: tags + depth of analysis





Constituency

- How do we know what the constituents are?
- Constituency tests:
  - Substitution by *proform* (e.g., pronoun)
  - Clefting (*It was with a spoon that…*)
  - Answer ellipsis (What did they eat? *the cake*)
    (How? *with a spoon*)



- Sometimes constituency is not clear, e.g., coordination: *she went to and bought food at the store*

Context-Free Grammars, CKY

Survey

- 1. The pace of the first few lectures (naive Bayes, logistic regression, perceptron, etc.) was [too fast/too slow/just right]
- 2. The pace of the last few lectures (tagging, Viterbi, parsing) was [too fast/too slow/just right]
- 3. The homeworks overall are [too hard/too easy/just right]
- 4. I would prefer A3 be due on [Friday March 8 / Monday March 11] (midterm is on Thursday, March 14)
- 5. Other comments (likes/dislikes)