PCFGs: Parsing & Evaluation

Deep Processing Techniques for NLP
Ling 571
January 23, 2017

Roadmap

- PCFGs:
  - Review: Definitions and Disambiguation

  - PCKY parsing
    - Algorithm and Example

  - Evaluation
    - Methods & Issues

  - Issues with PCFGs

PCFGs

- Probabilistic Context-free Grammars
  - Augmentation of CFGs

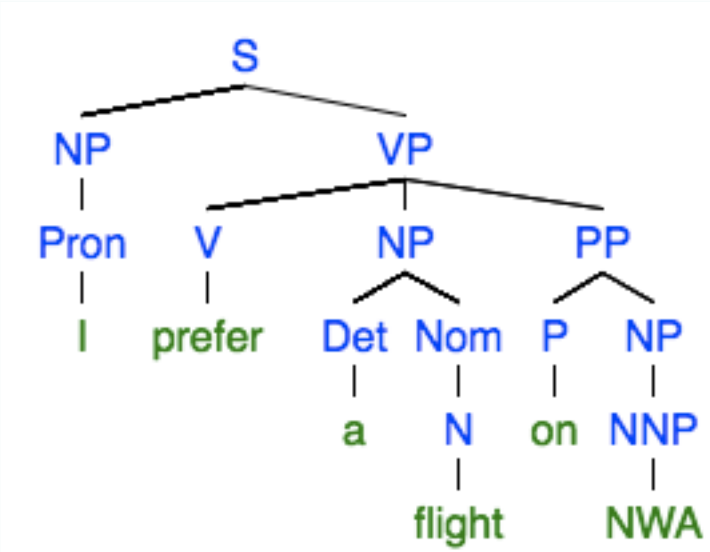
N	a set of **non-terminal symbols** (or **variables**)
Σ	a set of **terminal symbols** (disjoint from N)
R	a set of **rules** or productions, each of the form $A \rightarrow \beta\ \boxed{[p]}$,
	where A is a non-terminal,
	β is a string of symbols from the infinite set of strings $(\Sigma \cup N)*$,
	$\boxed{\text{and } p \text{ is a number between 0 and 1 expressing } P(\beta \mid A)}$
S	a designated **start symbol**

Disambiguation

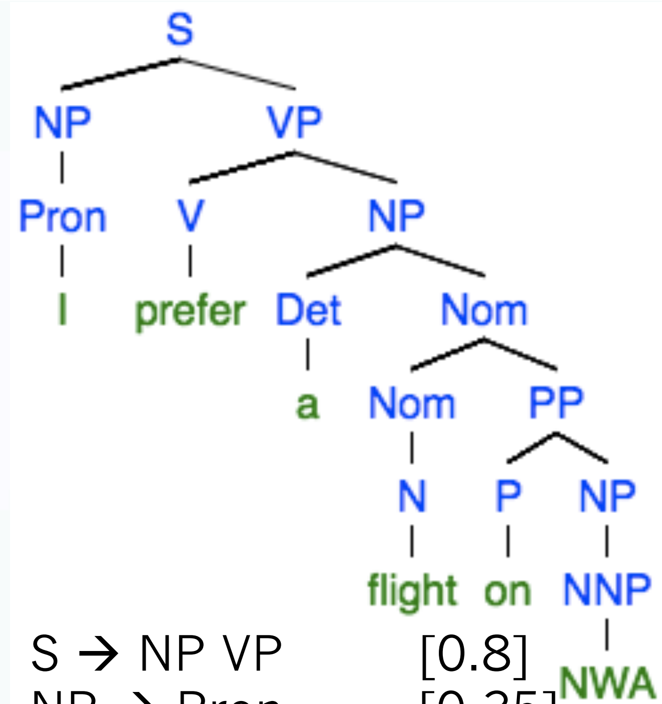
- A PCFG assigns probability to each parse tree T for input S.
  - Probability of T: product of all rules to derive T

$$P(T,S) = \prod_{i=1}^{n} P(RHS_i \mid LHS_i)$$

$$P(T,S) = P(T)P(S \mid T) = P(T)$$



S → NP VP	[0.8]
NP → Pron	[0.35]
Pron → I	[0.4]
VP → V NP PP	[0.1]
V → prefer	[0.4]
NP → Det Nom	[0.2]
Det → a	[0.3]
Nom → N	[0.75]
N → flight	[0.3]
PP → P NP	[1.0]
P → on	[0.2]
NP → NNP	[0.3]
NNP → NWA	[0.4]



S → NP VP	[0.8]
NP → Pron	[0.35]
Pron → I	[0.4]
VP → V NP	[0.2]
V → prefer	[0.4]
NP → Det Nom	[0.2]
Det → a	[0.3]
Nom → Nom PP	[0.05]
Nom → N	[0.75]
N → flight	[0.3]
PP → P NP	[1.0]
P → on	[0.2]
NP → NNP	[0.3]
NNP → NWA	[0.4]

Parsing Problem for PCFGs

- Select T such that:

$$\hat{T}(S) = \underset{Ts.t, S=yield(T)}{\operatorname{argmax}} P(T)$$

  - String of words S is *yield* of parse tree over S
  - Select tree that maximizes probability of parse

- Extend existing algorithms: e.g., CKY
  - Most modern PCFG parsers based on CKY
    - Augmented with probabilities

Probabilistic CKY

- Like regular CKY
  - Assume grammar in Chomsky Normal Form (CNF)
    - Productions:
      - A → B C or A → w
  - Represent input with indices b/t words
    - E.g., $_0$ Book $_1$ that $_2$ flight $_3$ through $_4$ Houston $_5$

- For input string length *n* and non-terminals *V*
  - Cell[i,j,A] in (n+1)x(n+1)xV matrix contains
    - Probability that constituent A spans [i,j]

Probabilistic CKY Algorithm

tion PROBABILISTIC-CKY(*words*,*grammar*) **returns** most probable parse
and its probability

$j \leftarrow$ **from** 1 **to** LENGTH(*words*) **do**

for all $\{ A \mid A \rightarrow words[j] \in grammar \}$

$table[j-1, j, A] \leftarrow P(A \rightarrow words[j])$

for $i \leftarrow$ **from** $j-2$ **downto** 0 **do**

for $k \leftarrow i+1$ **to** $j-1$ **do**

for all $\{ A \mid A \rightarrow BC \in grammar,$

and $table[i,k,B] > 0$ **and** $table[k,j,C] > 0 \}$

if $(table[i,j,A] < P(A \rightarrow BC) \times table[i,k,B] \times table[k,j,C])$ **then**

$table[i,j,A] \leftarrow P(A \rightarrow BC) \times table[i,k,B] \times table[k,j,C]$

$back[i,j,A] \leftarrow \{k, B, C\}$

return BUILD_TREE(*back*[1, LENGTH(*words*), *S*]), *table*[1, LENGTH(*words*), *S*]

PCKY Grammar Segment

- S → NP VP [0.80]
- NP → Det N [0.30]
- VP → V NP [0.20]
- V → includes [0.05]

- Det → the [0.40]
- Det → a [0.40]
- N → meal [0.01]
- N → flight [0.02]

PCKY Matrix: The flight includes a meal

Det: 0.4 **[0,1]**	**NP: 0.3*0.4*0.02 =.0024 [0,2]**	**[0,3]**	**[0,4]**	**S: 0.8* 0.000012* 0.0024 [0,5]**
	N: 0.02 [1,2]	[1,3]	[1,4]	[1,5]
		V: 0.05 [2,3]	[2,4]	VP: 0.2*0.05* 0.0012=0.000012 [2,5]
			Det: 0.4 [3,4]	NP: 0.3*0.4*0.01 =0.0012 [3,5]
				N: 0.01 [4,5]

Learning Probabilities

- Simplest way:
  - Treebank of parsed sentences
  - To compute probability of a rule, count:
    - Number of times non-terminal is expanded
    - Number of times non-terminal is expanded by given rule

$$P(\alpha \to \beta \mid \alpha) = \frac{Count(\alpha \to \beta)}{\sum_{\gamma} Count(\alpha \to \gamma)} = \frac{Count(\alpha \to \beta)}{Count(\alpha)}$$

  - Alternative: Learn probabilities by re-estimating
    - (Later)

Probabilistic Parser Development Paradigm

- Training:
  - (Large) Set of sentences with associated parses (Treebank)
    - E.g., Wall Street Journal section of Penn Treebank, sec 2-21
      - 39,830 sentences
    - Used to estimate rule probabilities
- Development (dev):
  - (Small) Set of sentences with associated parses (WSJ, 22)
    - Used to tune/verify parser; check for overfitting, etc.
- Test:
  - (Small-med) Set of sentences w/parses (WSJ, 23)
    - 2416 sentences
  - Held out, used for final evaluation

Parser Evaluation

- Assume a 'gold standard' set of parses for test set
- How can we tell how good the parser is?
- How can we tell how good a parse is?
  - Maximally strict: identical to 'gold standard'
  - Partial credit:
    - Constituents in output match those in reference
      - Same start point, end point, non-terminal symbol

Parseval

- How can we compute parse score from constituents?
- Multiple measures:
  - Labeled recall (LR):
    - $$\frac{\text{\# of correct constituents in hyp. parse}}{\text{\# of constituents in reference parse}}$$
  - Labeled precision (LP):
    - $$\frac{\text{\# of correct constituents in hyp. parse}}{\text{\# of total constituents in hyp. parse}}$$

Parseval (cont'd)

- F-measure:
  - Combines precision and recall

$$F_\beta = \frac{(\beta^2 + 1)PR}{\beta^2(P+R)}$$

  - F1-measure: $\beta = 1$ $$F_1 = \frac{2PR}{(P+R)}$$

- Crossing-brackets:
  - # of constituents where reference parse has bracketing ((A B) C) and hyp. has (A (B C))

Precision and Recall

- Gold standard
  - (S (NP (A a)) (VP (B b) (NP (C c)) (PP (D d))))
- Hypothesis
  - (S (NP (A a)) (VP (B b) (NP (C c) (PP (D d)))))
- G: S(0,4) NP(0,1) VP (1,4) NP (2,3) PP(3,4)
- H: S(0,4) NP(0,1) VP (1,4) NP (2,4) PP(3,4)
- LP: 4/5
- LR: 4/5
- F1: 4/5

State-of-the-Art Parsing

- Parsers trained/tested on *Wall Street Journal* PTB
  - LR: 90%+;
  - LP: 90%+;
  - Crossing brackets: 1%

- Standard implementation of Parseval: **evalb**

Evaluation Issues

- Constituents?
  - Other grammar formalisms
    - LFG, Dependency structure, ..
  - Require conversion to PTB format
- Extrinsic evaluation
  - How well does this match semantics, etc?