PCFG Parsing, Evaluation, & Improvements

Ling 571
Deep Processing Techniques for NLP
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Roadmap

- Parsing PCGFs:
  - Probabilistic CKY parsing
- Evaluation
  - Parseval
- Issues:
  - Positional and lexical independence assumptions
- Improvements:
  - Lexicalization: PLCFGs

Parsing Problem for PCFGs

- Select T such that:

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

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

- Extend existing algorithms: CKY & Earley
  - 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

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

  for $j \leftarrow$ **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	$\rightarrow$	$NP\ VP$	.80	Det	$\rightarrow$	the	.40
NP	$\rightarrow$	$Det\ N$	.30	Det	$\rightarrow$	a	.40
VP	$\rightarrow$	$V\ NP$	.20	N	$\rightarrow$	$meal$	.01
V	$\rightarrow$	$includes$	.05	N	$\rightarrow$	$flight$	.02

PCKY Matrix: The flight includes a meal

Det: 0.4 **[0,1]**				

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	N: 0.2 [1,2]	[1,3]		
		V: 0.05 [2,3]		

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	N: 0.2 [1,2]	[1,3]		
		V: 0.05 [2,3]		
			Det: 0.4 [3,4]	

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

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	N: 0.2 [1,2]	[1,3]	[1,4]	
		V: 0.05 [2,3]	[2,4]	
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		V: 0.05 [2,3]	[2,4]	VP: 0.2*0.05* 0.0012=0.0 00012 [2,5]
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Det: 0.4 **[0,1]**	**NP: 0.3*0.4*0.02 =.0024 [0,2]**	**[0,3]**	**[0,4]**	**S: 0.000012* 0.0024 [0.5]**
	N: 0.2 [1,2]	[1,3]	[1,4]	[1,5]
		V: 0.05 [2,3]	[2,4]	VP: 0.2*0.05* 0.0012=0.0 00012 [2,5]
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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

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- Development (dev):
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    - 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?
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- 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):
    - # of correct constituents in hyp. parse
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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: $\beta = 1$ $\quad F_1 = \frac{2PR}{(P + R)}$
- 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)))))

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- LR: 4/5

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- 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?

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    - LFG, Dependency structure, ..
  - Require conversion to PTB format

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

Parser Issues

- PCFGs make many (unwarranted) independence assumptions
  - Structural Dependency
    - NP -> Pronoun: much more likely in subject position
  - Lexical Dependency
    - Verb subcategorization
    - Coordination ambiguity

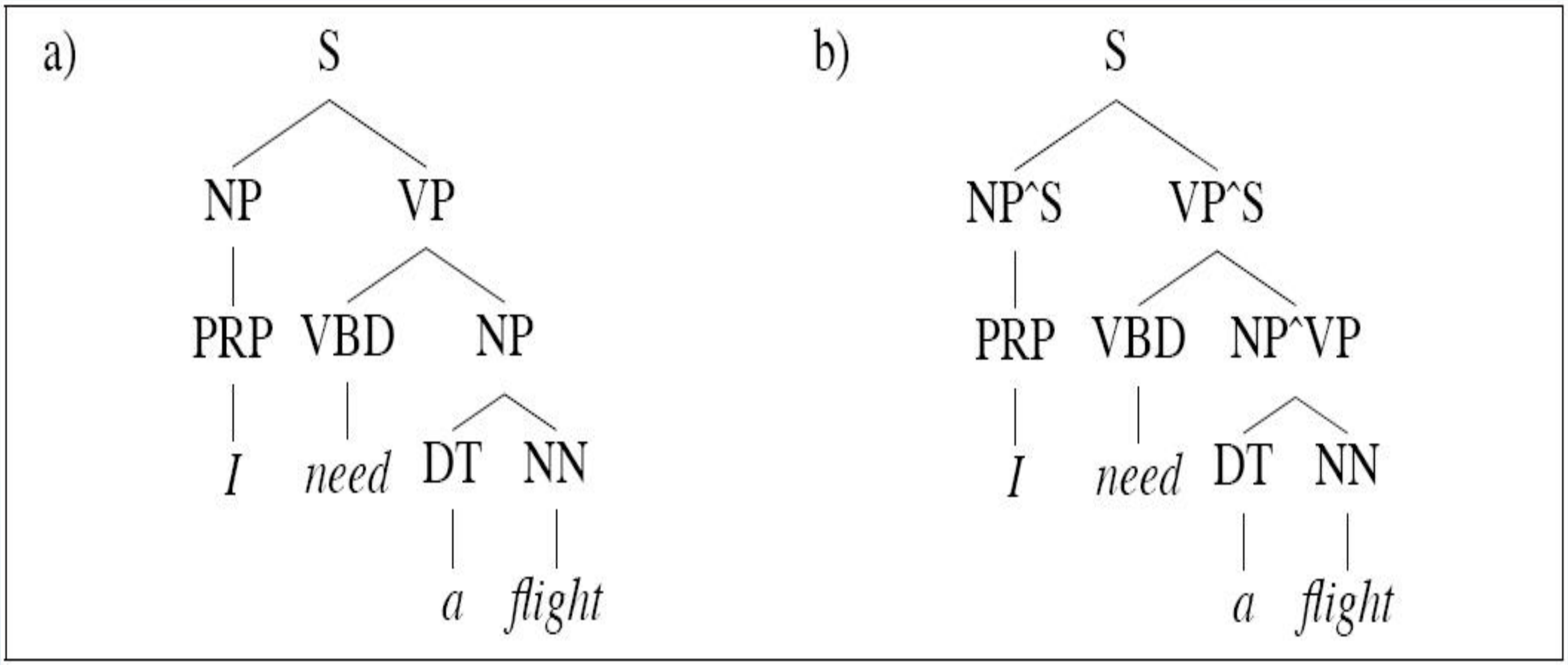
Improving PCFGs: Structural Dependencies

- How can we capture Subject/Object asymmetry?
  - E.g., NP_{subj}-> Pron vs NP_{Obj}->Pron

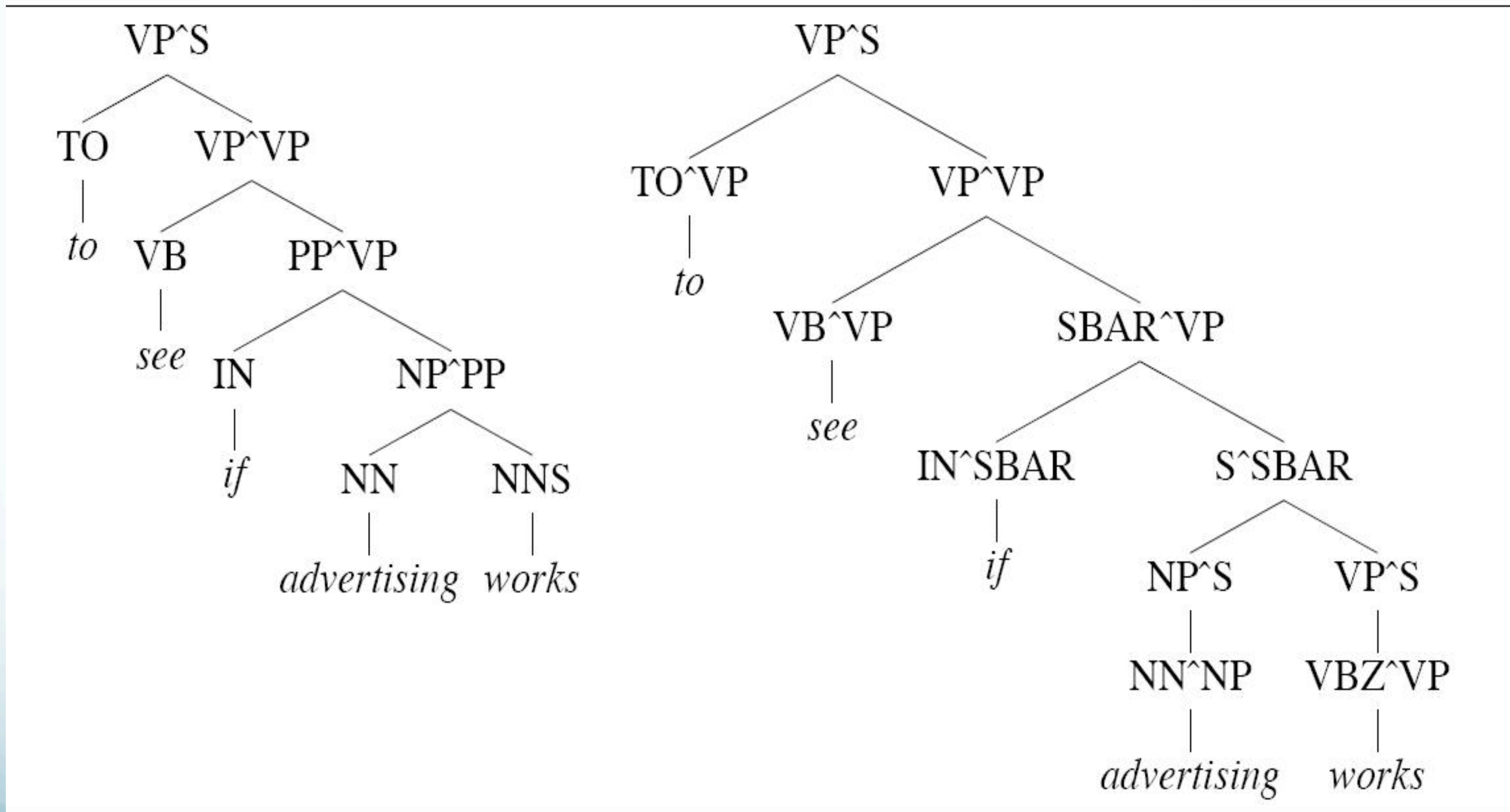
- Parent annotation:
  - Annotate each node with parent in parse tree
    - E.g., NP^S vs NP^VP
    - Also annotate pre-terminals:
      - RB^ADVP vs RB^VP
      - IN^SBAR vs IN^PP

- Can also split rules on other conditions

Parent Annotation



Parent Annotation: Pre-terminals



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- Advantages:
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- Disadvantages:
  - Increases number of rules in grammar
  - Decreases amount of training per rule

    - Strategies to search for optimal # of rules

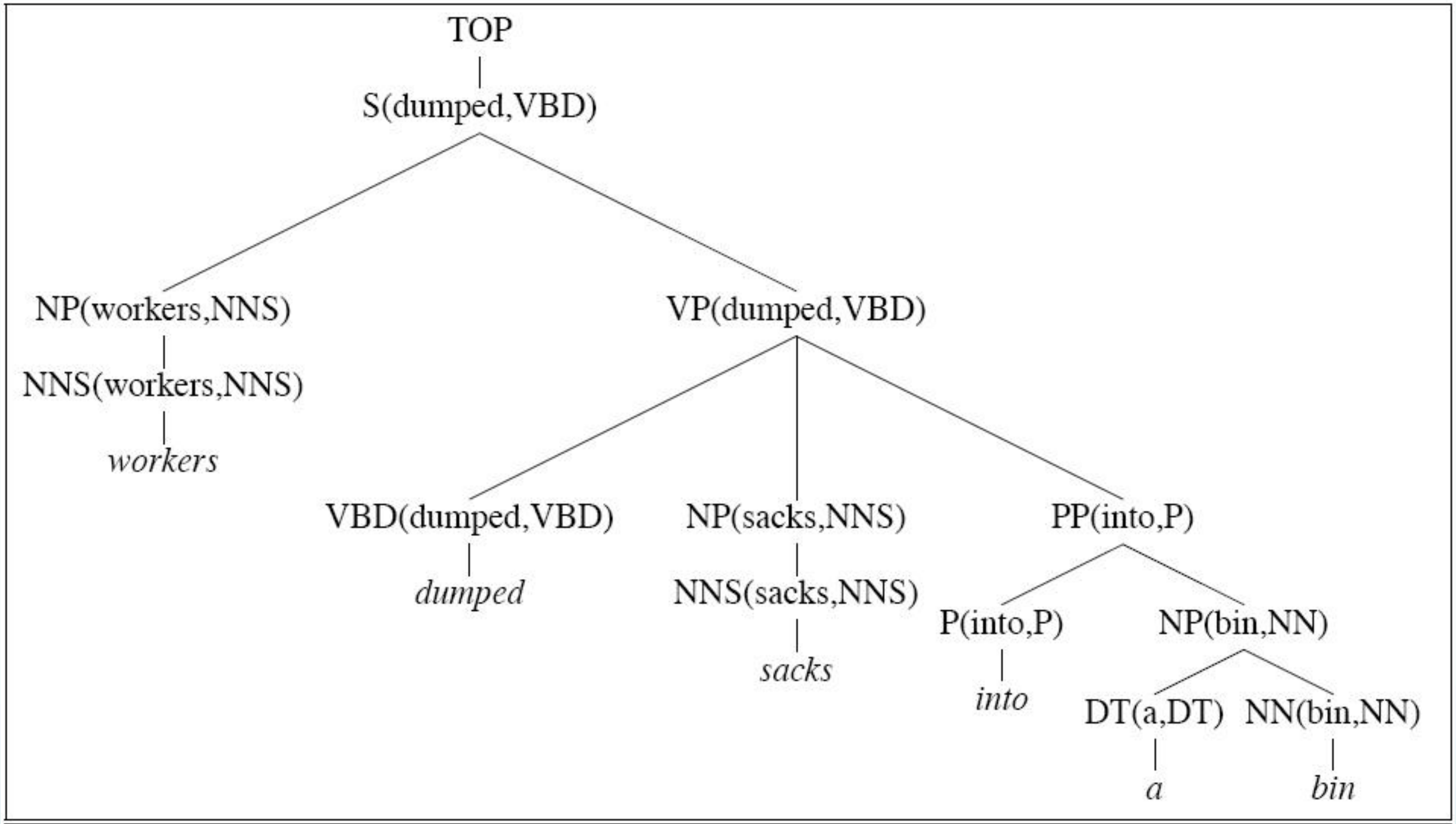
Improving PCFGs: Lexical Dependencies

- Lexicalized rules:
  - Best known parsers: Collins, Charniak parsers
  - Each non-terminal annotated with its lexical head
    - E.g. verb with verb phrase, noun with noun phrase
  - Each rule must identify RHS element as head
    - Heads propagate up tree
  - Conceptually like adding 1 rule per head value
    - VP(dumped) -> VBD(dumped)NP(sacks)PP(into)
    - VP(dumped) -> VBD(dumped)NP(cats)PP(into)

Lexicalized PCFGs

- Also, add head tag to non-terminals
  - Head tag: Part-of-speech tag of head word
    - VP(dumped) -> VBD(dumped)NP(sacks)PP(into)
    - VP(dumped,VBD) -> VBD(dumped,VBD)NP(sacks,NNS) PP(into,IN)

- Two types of rules:
  - Lexical rules: pre-terminal -> word
    - Deterministic, probability 1
  - Internal rules: all other expansions
    - Must estimate probabilities



Internal Rules					**Lexical Rules**		
TOP	→	S(dumped,VBD)			NNS(workers,NNS)	→	workers
S(dumped,VBD)	→	NP(workers,NNS)	VP(dumped,VBD)		VBD(dumped,VBD)	→	dumped
NP(workers,NNS)	→	NNS(workers,NNS)			NNS(sacks,NNS)	→	sacks
VP(dumped,VBD)	→	VBD(dumped, VBD)	NP(sacks,NNS)	PP(into,P)	P(into,P)	→	into
PP(into,P)	→	P(into,P)	NP(bin,NN)		DT(a,DT)	→	a
NP(bin,NN)	→	DT(a,DT)	NN(bin,NN)		NN(bin,NN)	→	bin

PLCFGs

- Issue:

PLCFGs

- Issue: Too many rules
  - No way to find corpus with enough examples

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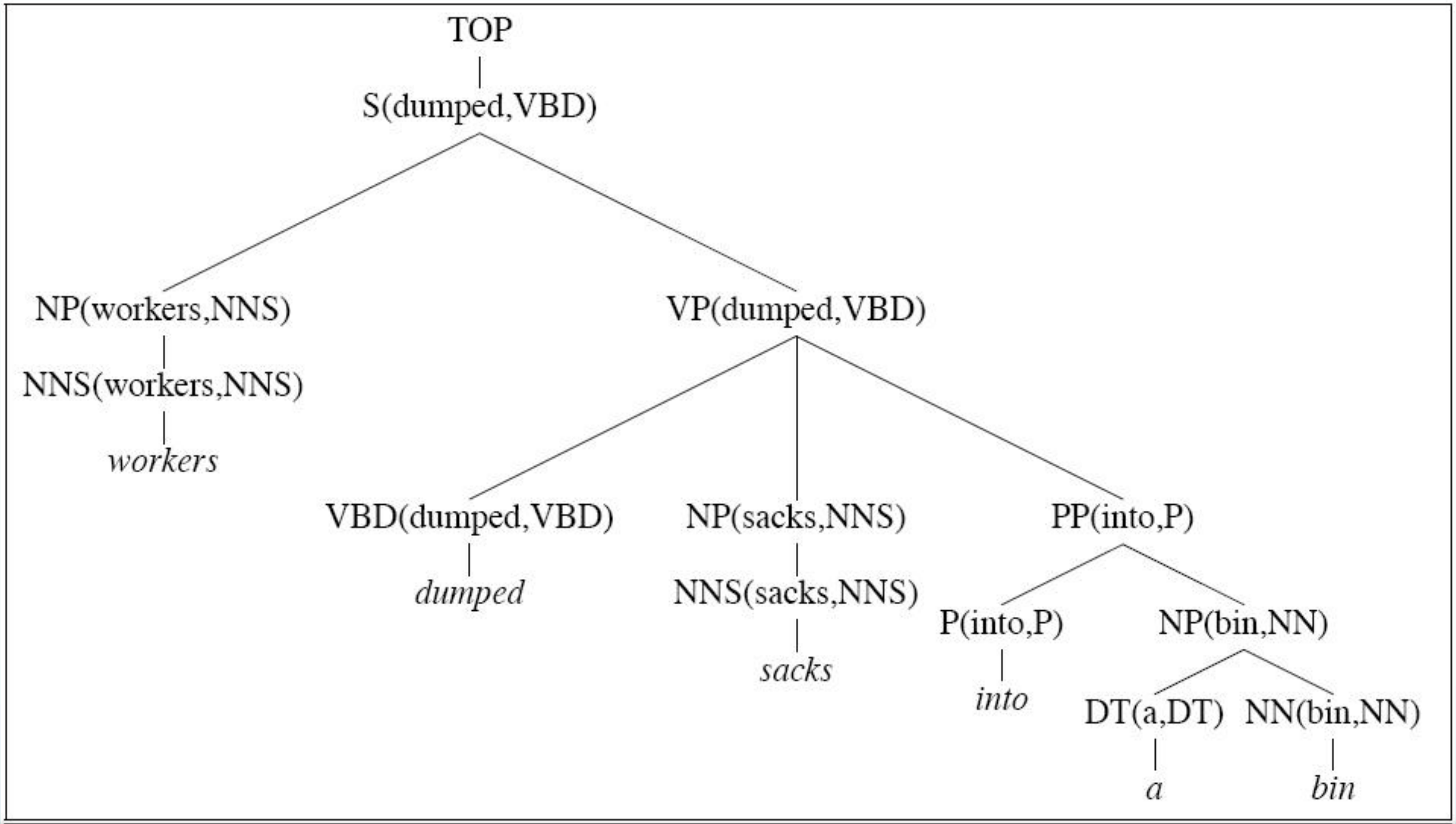
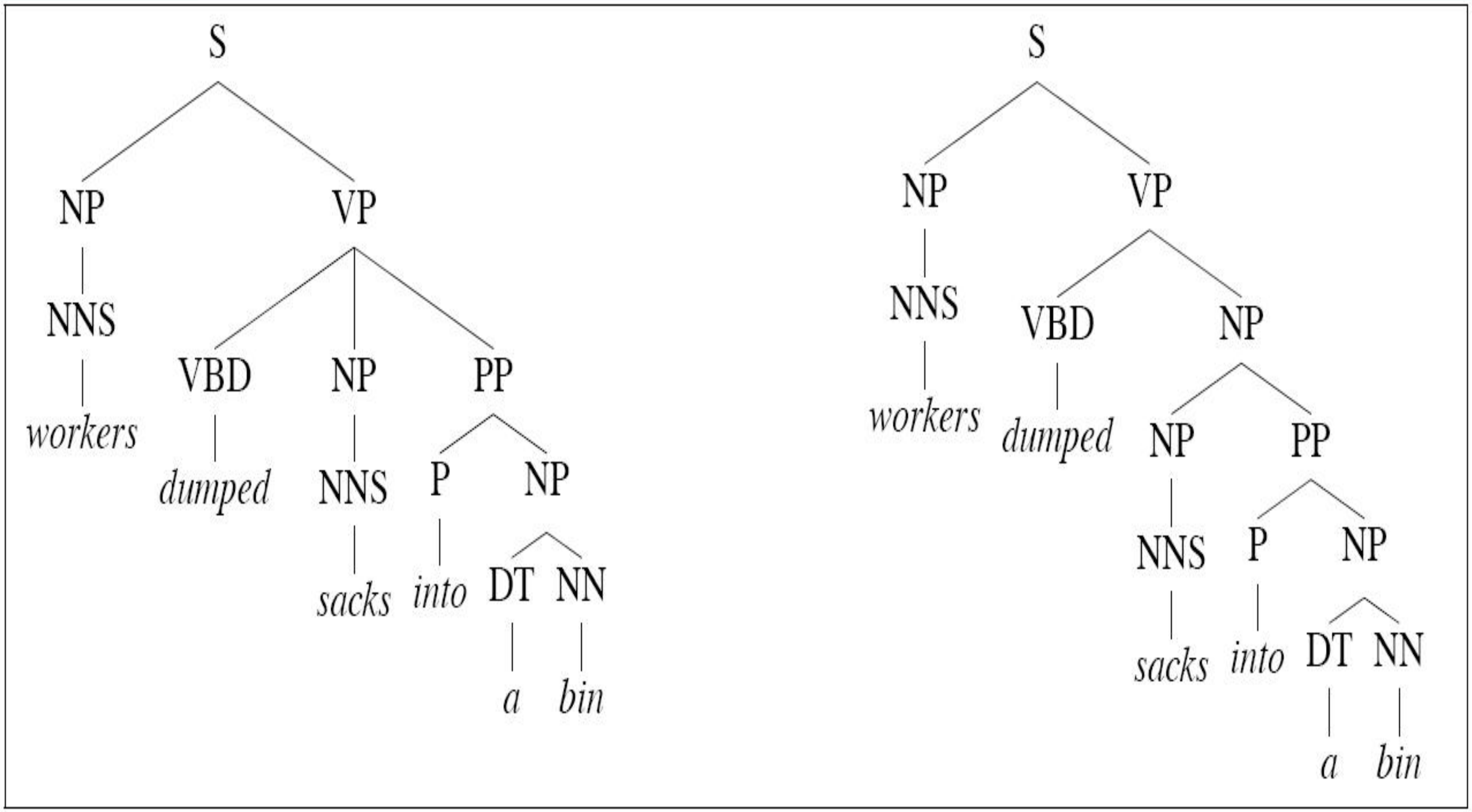
  - No way to find corpus with enough examples
- (Partial) Solution: Independence assumed
  - Condition rule on
    - Category of LHS, head
  - Condition head on
    - Category of LHS and parent's head

$$P(T,S) = \prod_{n \in T} p(r(n) \mid n, h(n)) * p(h(n) \mid n, h(m(n)))$$


TOP
S(dumped,VBD)
NP(workers,NNS)
VP(dumped,VBD)
NNS(workers,NNS)
workers
VBD(dumped,VBD)
NP(sacks,NNS)
PP(into,P)
dumped
NNS(sacks,NNS)
sacks
P(into,P)
NP(bin,NN)
into
DT(a,DT)
NN(bin,NN)
a
bin

Disambiguation Example



Disambiguation Example

$$P(VP \to VBD\,NP\,PP \mid VP, dumped) = \frac{C(VP(dumped) \to VBD\,NP\,PP)}{\sum_{\beta} C(VP(dumped) \to \beta)} = 6/9 = 0.67$$

$$p(VP \to VBD\,NP \mid VP, dumped) = \frac{C(VP(dumped) \to VBD\,NP)}{\sum_{\beta} C(VP(dumped) \to \beta)} = 0/9 = 0$$

$$p(in \mid PP, dumped) = \frac{C(X(dumped) \to ...PP(in)..)}{\sum_{\beta} C(X(dumped) \to ...PP...)} = 2/9 = 0.22$$

$$p(in \mid PP, sacks) = \frac{C(X(sacks) \to ...PP(in)...)}{\sum_{\beta} C(X(sacks) \to ...PP...)} = 0/0$$