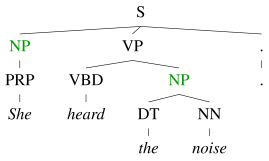
Statistical NLP
Spring 2008

Lecture 16: PCFGs

Dan Klein – UC Berkeley

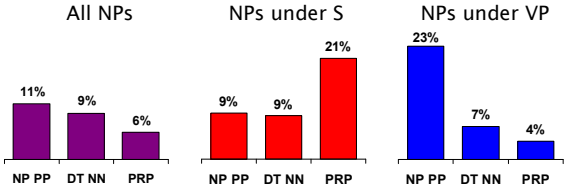
Context Freedom?



- Not every NP expansion can fill every NP slot
  - A grammar with symbols like "NP" won't be context-free
  - Statistically, treebank symbols represent overly strong conditional independence assumptions

Non-Independence I

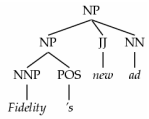
- Independence assumptions are often too strong.

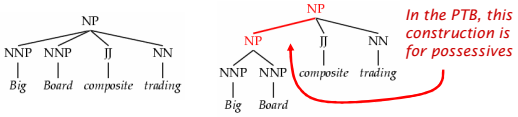


- Example: the expansion of an NP is highly dependent on the parent of the NP (i.e., subjects vs. objects).
- Also: the subject and object expansions are correlated!

Non-Independence II

- Who cares?
  - NB, HMMs, all make false assumptions!
  - For generation, consequences would be obvious.
  - For parsing, does it impact accuracy?
- Symptoms of overly strong assumptions:
  - Rewrites get used where they don't belong.
  - Rewrites get used too often or too rarely.

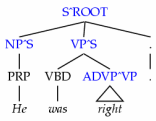




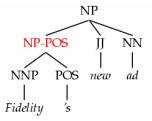
Breaking Up the Symbols

- We can relax independence assumptions by encoding dependencies into the PCFG symbols:

Parent annotation [Johnson 98]



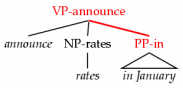
Marking possessive NPs



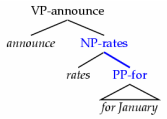
- What are the most useful "features" to encode?

Lexicalization

- Lexical heads important for certain classes of ambiguities (e.g., PP attachment):



- Lexicalizing grammar creates a much larger grammar. (cf. next week)
  - Sophisticated smoothing needed
  - Smarter parsing algorithms
  - More data needed
- How necessary is lexicalization?
  - Bilexical vs. monolexical selection
  - Closed vs. open class lexicalization



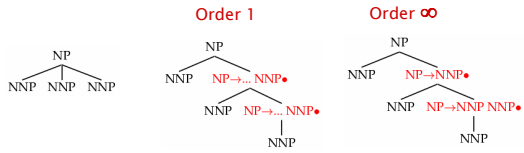
Typical Experimental Setup

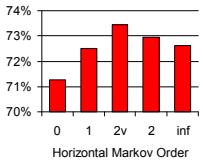
- Corpus: Penn Treebank, WSJ

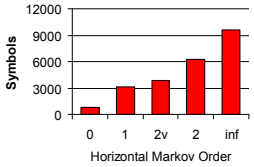
Training:	sections	02-21
Development:	section	22 (here, first 20 files)
Test:	section	23

- Accuracy – F1: harmonic mean of per-node labeled precision and recall.
- Here: also size – number of symbols in grammar.
  - Passive / complete symbols: NP, NP^S
  - Active / incomplete symbols: NP → NP CC •

Horizontal Markovization

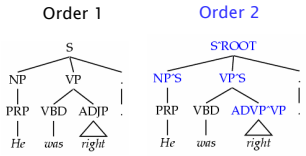


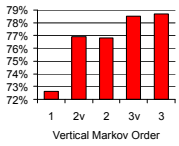


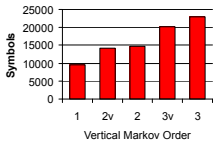


Vertical Markovization

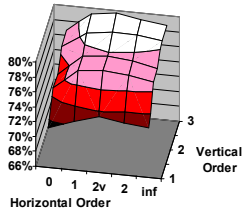
- Vertical Markov order: rewrites depend on past k ancestor nodes. (cf. parent annotation)

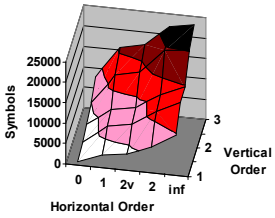






Vertical and Horizontal



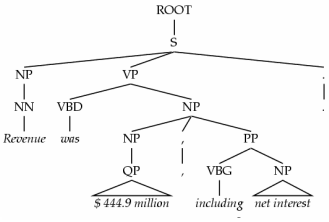


- Examples:
  - Raw treebank: v=1, h=∞
  - Johnson 98: v=2, h=∞
  - Collins 99: v=2, h=2
  - Best F1: v=3, h=2v

Model	F1	Size
Base: v=h=2v	77.8	7.5K

Unary Splits

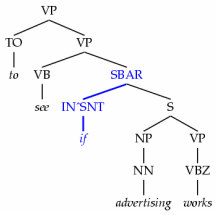
- Problem: unary rewrites used to transmute categories so a high-probability rule can be used.
- Solution: Mark unary rewrite sites with -U



Annotation	F1	Size
Base	77.8	7.5K
UNARY	78.3	8.0K

Tag Splits

- Problem: Treebank tags are too coarse.
- Example: Sentential, PP, and other prepositions are all marked IN.



- Partial Solution:
  - Subdivide the IN tag.

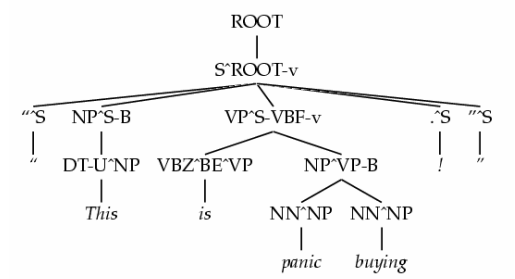
Annotation	F1	Size
Previous	78.3	8.0K
SPLIT-IN	80.3	8.1K

Other Tag Splits

- UNARY-DT: mark demonstratives as DT^U ("the X" vs. "those")
- UNARY-RB: mark phrasal adverbs as RB^U ("quickly" vs. "very")
- TAG-PA: mark tags with non-canonical parents ("not" is an RB^VP)
- SPLIT-AUX: mark auxiliary verbs with –AUX [cf. Charniak 97]
- SPLIT-CC: separate "but" and "&" from other conjunctions
- SPLIT-%: "%" gets its own tag.

F1	Size
80.4	8.1K
80.5	8.1K
81.2	8.5K
81.6	9.0K
81.7	9.1K
81.8	9.3K

A Fully Annotated (Unlex) Tree

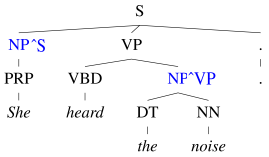


Some Test Set Results

Parser	LP	LR	**F1**	CB	0 CB
Magerman 95	84.9	84.6	**84.7**	1.26	56.6
Collins 96	86.3	85.8	**86.0**	1.14	59.9
Unlexicalized	86.9	85.7	**86.3**	1.10	60.3
Charniak 97	87.4	87.5	**87.4**	1.00	62.1
Collins 99	88.7	88.6	**88.6**	0.90	67.1

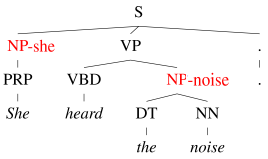
- Beats "first generation" lexicalized parsers.
- Lots of room to improve – more complex models next.

The Game of Designing a Grammar



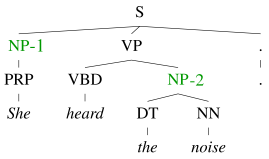
- Annotation refines base treebank symbols to improve statistical fit of the grammar
  - Parent annotation [Johnson '98]

The Game of Designing a Grammar



- Annotation refines base treebank symbols to improve statistical fit of the grammar
  - Parent annotation [Johnson '98]
  - Head lexicalization [Collins '99, Charniak '00]

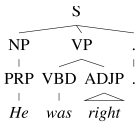
The Game of Designing a Grammar



- Annotation refines base treebank symbols to improve statistical fit of the grammar
  - Parent annotation [Johnson '98]
  - Head lexicalization [Collins '99, Charniak '00]
  - Automatic clustering?

Manual Annotation

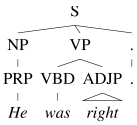
- Manually split categories
  - NP: subject vs object
  - DT: determiners vs demonstratives
  - IN: sentential vs prepositional
- Advantages:
  - Fairly compact grammar
  - Linguistic motivations
- Disadvantages:
  - Performance leveled out
  - Manually annotated



Model	*F1*
Naïve Treebank Grammar	72.6
Klein & Manning '03	86.3

Automatic Annotation Induction

- Advantages:
  - Automatically learned:
    Label *all* nodes with latent variables.
    Same number k of subcategories for all categories.
- Disadvantages:
  - Grammar gets too large
  - Most categories are oversplit while others are undersplit.

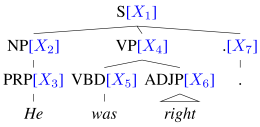


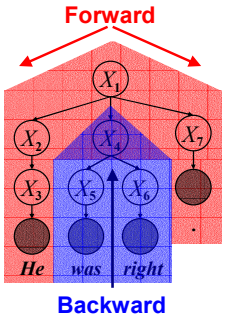
Model	*F1*
Klein & Manning '03	86.3
Matsuzaki et al. '05	86.7

Learning Latent Annotations

EM algorithm:

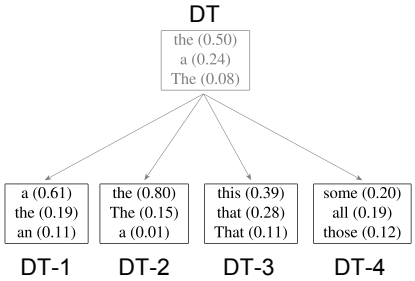
- Brackets are known
- Base categories are known
- Only induce subcategories



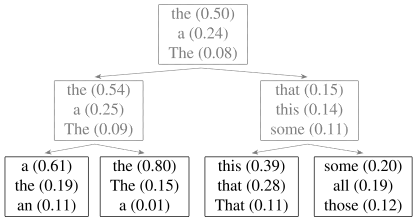


Just like Forward-Backward for HMMs.

Refinement of the DT tag

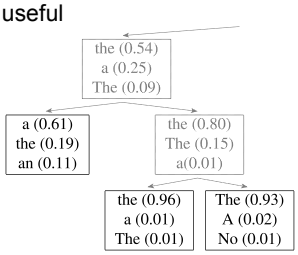


Hierarchical refinement



Adaptive Splitting

- Want to split complex categories more
- Idea: split everything, roll back splits which were least useful

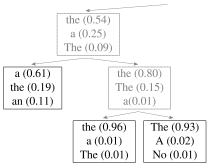


Adaptive Splitting

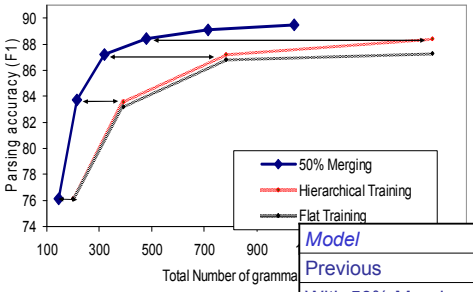
- Evaluate loss in likelihood from removing each split =

$$\frac{\textit{Data likelihood with split reversed}}{\textit{Data likelihood with split}}$$

- No loss in accuracy when 50% of the splits are reversed.



Adaptive Splitting Results



Model	*F1*
Previous	88.4
With 50% Merging	89.5

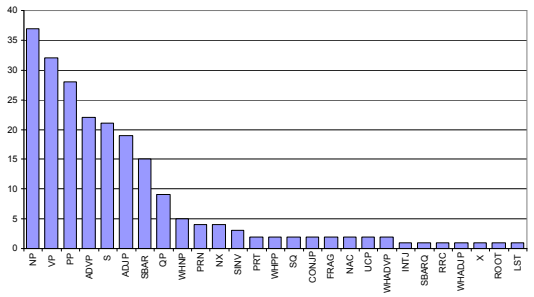
Final Results (Accuracy)

		≤ 40 words F1	all F1
ENG	Charniak&Johnson '05 (generative)	90.1	89.6
	Petrov and Klein 07	**90.6**	**90.1**
GER	Dubey '05	76.3	-
	Petrov and Klein 07	**80.8**	**80.1**
CHN	Chiang et al. '02	80.0	76.6
	Petrov and Klein 07	**86.3**	**83.4**

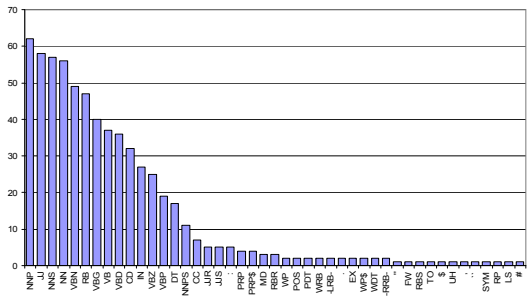
Final Results

Parser	*F1 ≤ 40 words*	*F1 all words*
Klein & Manning '03	86.3	85.7
Matsuzaki et al. '05	86.7	86.1
Collins '99	88.6	88.2
Charniak & Johnson '05	90.1	89.6
Petrov et. al. 06	**90.2**	**89.7**

Number of Phrasal Subcategories



Number of Lexical Subcategories



Learned Splits

- Proper Nouns (NNP):

NNP-14	Oct.	Nov.	Sept.
NNP-12	John	Robert	James
NNP-2	J.	E.	L.
NNP-1	Bush	Noriega	Peters
NNP-15	New	San	Wall
NNP-3	York	Francisco	Street

- Personal pronouns (PRP):

PRP-0	It	He	I
PRP-1	it	he	they
PRP-2	it	them	him

Learned Splits

- Relative adverbs (RBR):

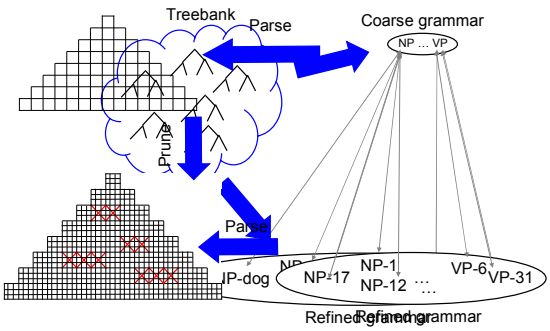
RBR-0	further	lower	higher
RBR-1	more	less	More
RBR-2	earlier	Earlier	later

- Cardinal Numbers (CD):

CD-7	one	two	Three
CD-4	1989	1990	1988
CD-11	million	billion	trillion
CD-0	1	50	100
CD-3	1	30	31
CD-9	78	58	34

[Goodman '97, Charniak&Johnson '05]

Coarse-to-Fine Parsing

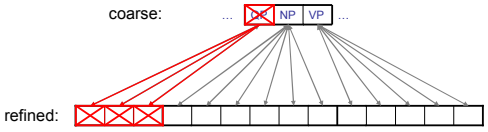


Prune?

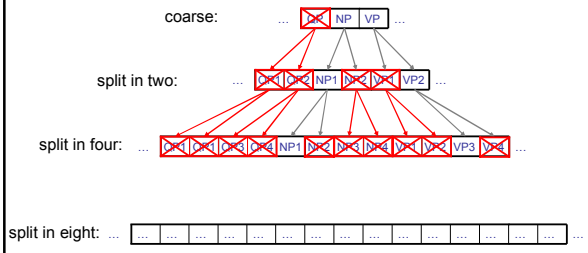
For each chart item $X[i,j]$, compute posterior probability:

$$\frac{\mathrm{P}_{\mathrm{IN}}(X,i,j)\cdot\mathrm{P}_{\mathrm{OUT}}(X,i,j)}{\mathrm{P}_{\mathrm{IN}}(root,0,n)} < \textit{threshold}$$

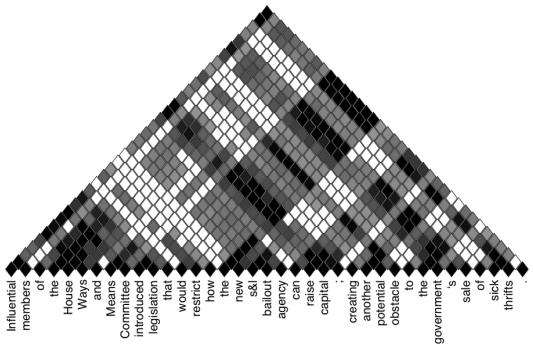
E.g. consider the span 5 to 12:



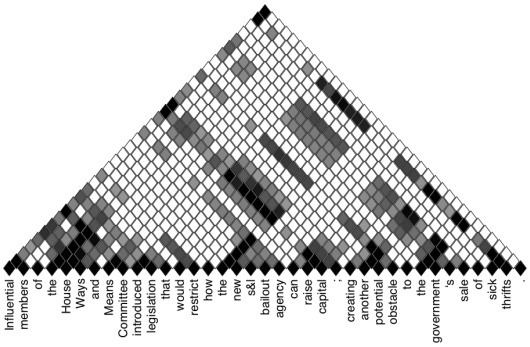
Hierarchical Pruning



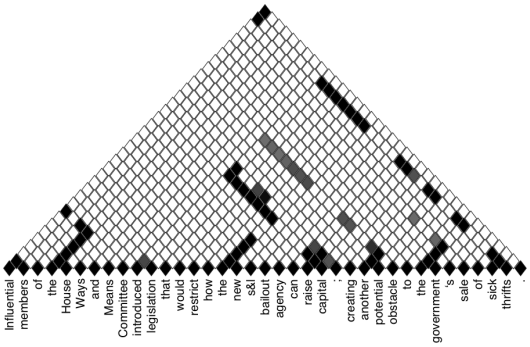
Bracket Posteriors (after G_0)



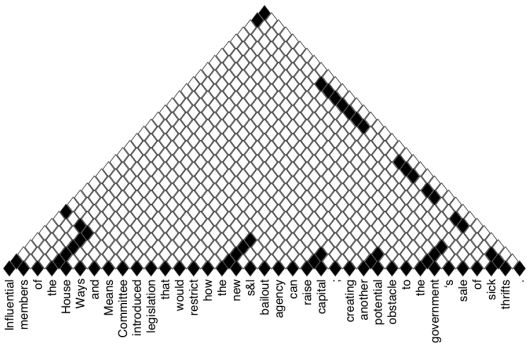
Bracket Posteriors (after G_1)



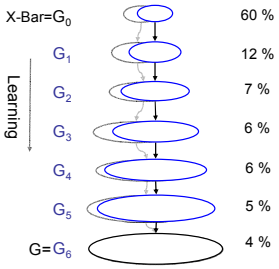
Bracket Posteriors (Final)



Bracket Posteriors (Best Tree)



Parsing times



1621 min

111 min

35 min

15 min

(no search error)