# Statistical NLP
## Spring 2007


Lecture 14: Parsing I

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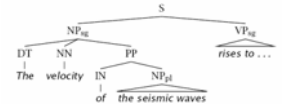
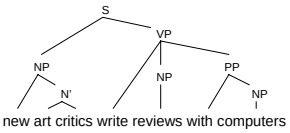
## Phrase Structure Parsing

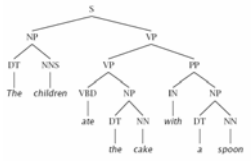
- Phrase structure parsing organizes syntax into *constituents* or *brackets*
- In general, this involves nested trees
- Linguists can, and do, argue about details
- Lots of ambiguity
- Not the only kind of syntax…



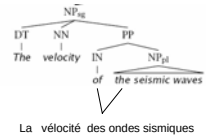

## Constituency Tests

- How do we know what nodes go in the tree?
- Classic constituency tests:
  - Substitution by *proform*
  - Question answers
  - Semantic reference
  - Dislocation
- Cross-linguistic arguments, too



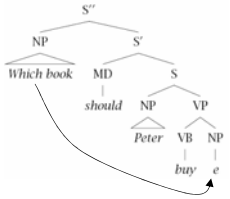

## Conflicting Tests

- Constituency isn't always clear
  - Units of transfer:
    - think about ~ penser à
    - talk about ~ hablar de
  - Phonological reduction:
    - I will go → I'll go
    - I want to go → I wanna go
    - a le centre → au centre



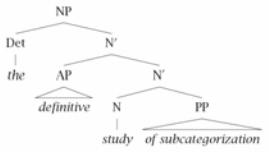

## Non-Local Phenomena

- Dislocation / gapping
  - Why did the postman think that the neighbors were home?
  - A debate arose which continued until the election.
- Binding
  - Reference
    - The IRS audits itself
  - Control
    - I want to go
    - I want you to go

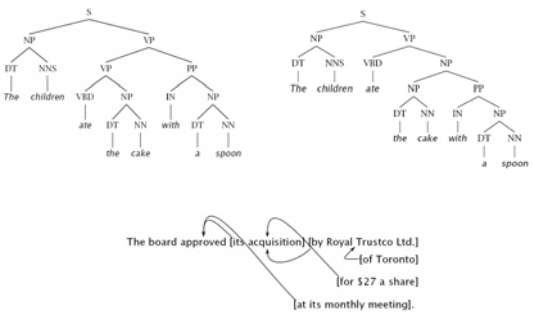



## Regularity of Rules

- Argumentation
- Adjunction
- Coordination
- X' Theory



## PP Attachment







## PP Attachment

| V | N1 | P | N2 | Attachment |
|---|---|---|---|---|
| join | board | as | director | V |
| is | chairman | of | N.V. | N |
| using | crocidolite | in | filters | V |
| bring | attention | to | problem | V |
| is | asbestos | in | products | N |
| making | paper | for | filters | N |
| including | three | with | cancer | N |

| Method | Accuracy |
|---|---|
| Always noun attachment | 59.0 |
| Most likely for each preposition | 72.2 |
| Average Human (4 head words only) | 88.2 |
| Average Human (whole sentence) | 93.2 |

## Attachment is a Simplification

- I cleaned the dishes from dinner
- I cleaned the dishes with detergent
- I cleaned the dishes in the sink

## Syntactic Ambiguities I

- Prepositional phrases:
  *They cooked the beans in the pot on the stove with handles.*
- Particle vs. preposition:
  *A good pharmacist dispenses with accuracy.*
  *The puppy tore up the staircase.*
- Complement structures
  *The tourists objected to the guide that they couldn't hear.*
  *She knows you like the back of her hand.*
- Gerund vs. participial adjective
  *Visiting relatives can be boring.*
  *Changing schedules frequently confused passengers.*

## Syntactic Ambiguities II

- Modifier scope within NPs
  *impractical design requirements*
  *plastic cup holder*
- Multiple gap constructions
  *The chicken is ready to eat.*
  *The contractors are rich enough to sue.*
- Coordination scope:
  *Small rats and mice can squeeze into holes or cracks in the wall.*

## Treebank Sentences

```
( (S (NP-SBJ The move)
     (VP followed
         (NP (NP a round)
             (PP of
                 (NP (NP similar increases)
                     (PP by
                         (NP other lenders))
                     (PP against
                         (NP Arizona real estate loans)))))
         ,
         (S-ADV (NP-SBJ *)
                (VP reflecting
                    (NP (NP a continuing decline)
                        (PP-LOC in
                                (NP that market))))))
     .))
```

## Human Processing

- Garden pathing:

  the man who hunts ducks out on weekends

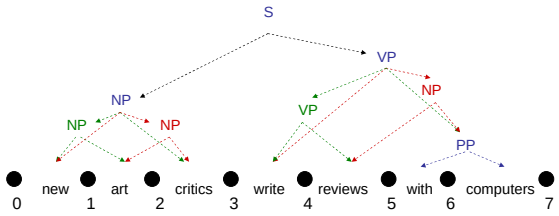
  the cotton shirts are made from grows in Mississippi

  the daughter of the king's son loves himself

- Ambiguity maintenance

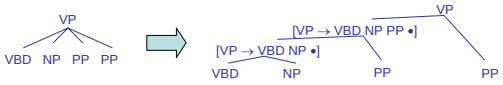
  Have the police … eaten their supper?
  come in and look around.
  taken out and shot.

## The Parsing Problem



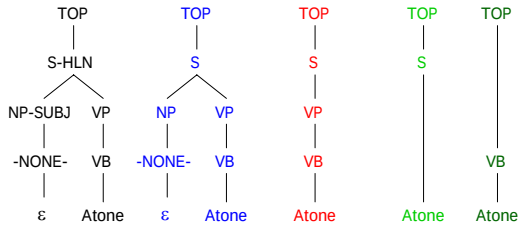

## Chomsky Normal Form

- Chomsky normal form:
  - All rules of the form X → Y Z or X → w
  - In principle, this is no limitation on the space of (P)CFGs
    - N-ary rules introduce new non-terminals




    - Unaries / empties are "promoted"
  - In practice it's kind of a pain:
    - Reconstructing n-aries is easy
    - Reconstructing unaries is trickier
    - The straightforward transformations don't preserve tree scores
  - Makes parsing algorithms simpler!

## Unaries in Grammars




## A Recursive Parser

- Here's a recursive (CNF) parser:

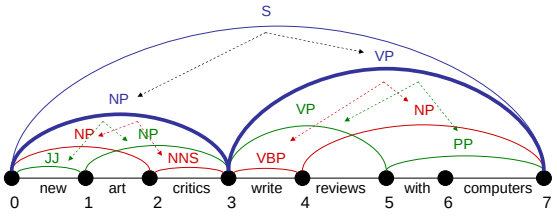
```
bestParse(X,i,j,s)
  if (j = i+1)
      return X -> s[i]
  (X->YZ,k) = argmax score(X->YZ) *
                     bestScore(Y,i,k,s) *
                     bestScore(Z,k,j,s)
  parse.parent = X
  parse.leftChild = bestParse(Y,i,k,s)
  parse.rightChild = bestParse(Z,k,j,s)
  return parse
```

## A Recursive Parser

```
bestScore(X,i,j,s)
  if (j = i+1)
      return tagScore(X,s[i])
  else
      return max score(X->YZ) *
                 bestScore(Y,i,k) *
                 bestScore(Z,k,j)
```

- Will this parser work?
- Why or why not?
- Memory requirements?

# An Example




# A Memoized Parser

- One small change:

```
bestScore(X,i,j,s)
   if (scores[X][i][j] == null)
       if (j = i+1)
           score = tagScore(X,s[i])
       else
           score = max score(X->YZ) *
                       bestScore(Y,i,k) *
                       bestScore(Z,k,j)
       scores[X][i][j] = score
   return scores[X][i][j]
```

# Memory: Theory

- How much memory does this require?
  - Have to store the score cache
  - Cache size: |symbols|*$n^2$ doubles
  - For the plain treebank grammar:
    - X ~ 20K, n = 40, double ~ 8 bytes = ~ 256MB
    - Big, but workable.
- What about sparsity?

# Time: Theory

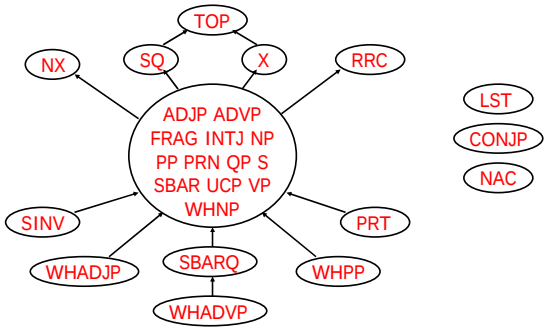
- How much time will it take to parse?
  - Have to fill each cache element (at worst)
  - Each time the cache fails, we have to:
    - Iterate over each rule X → Y Z and split point k
    - Do constant work for the recursive calls
  - Total time: |rules|*$n^3$
  - Cubic time
  - Something like 5 sec for an unoptimized parse of a 20-word sentences

# Unary Rules

- Unary rules?

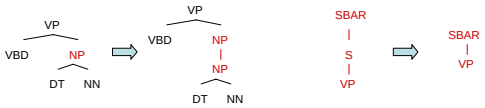
```
bestScore(X,i,j,s)
   if (j = i+1)
       return tagScore(X,s[i])
   else
       return max max score(X->YZ) *
                       bestScore(Y,i,k) *
                       bestScore(Z,k,j)
                  max score(X->Y) *
                       bestScore(Y,i,j)
```

# Same-Span Reachability



## CNF + Unary Closure

- We need unaries to be non-cyclic
  - Can address by pre-calculating the *unary closure*
  - Rather than having zero or more unaries, always have exactly one




  - Alternate unary and binary layers
  - Reconstruct unary chains afterwards

## Alternating Layers

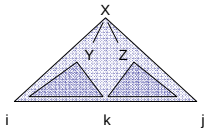
```
bestScoreB(X,i,j,s)
     return max max score(X->YZ) *
                  bestScoreU(Y,i,k) *
                  bestScoreU(Z,k,j)


bestScoreU(X,i,j,s)
   if (j = i+1)
       return tagScore(X,s[i])
   else
       return max max score(X->Y) *
                  bestScoreB(Y,i,j)
```

## A Bottom-Up Parser (CKY)

- Can also organize things bottom-up

```
bestScore(s)
   for (i : [0,n-1])
     for (X : tags[s[i]])
       score[X][i][i+1] =
          tagScore(X,s[i])
   for (diff : [2,n])
     for (i : [0,n-diff])
       j = i + diff
       for (X->YZ : rule)
         for (k : [i+1, j-1])
           score[X][i][j] = max score[X][i][j],
                                score(X->YZ) *
                                score[Y][i][k] *
                                score[Z][k][j]
```




## Efficient CKY

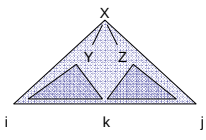
- Lots of tricks to make CKY efficient
  - Most of them are little engineering details:
    - E.g., first choose k, then enumerate through the Y:[i,k] which are non-zero, then loop through rules by left child.
    - Optimal layout of the dynamic program depends on grammar, input, even system details.
  - Another kind is more critical:
    - Many X:[i,j] can be suppressed on the basis of the input string
    - We'll see this next class as figures-of-merit or A* heuristics

## Memory: Practice

- Memory:
  - Still requires memory to hold the score table
- Pruning:
  - score[X][i][j] can get too large (when?)
  - can instead keep beams scores[i][j] which only record scores for the top K symbols found to date for the span [i,j]

## Time: Theory

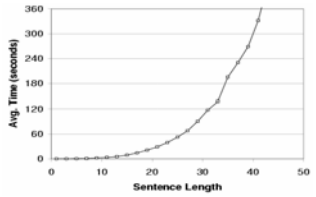
- How much time will it take to parse?
  - For each diff (<= n)
    - For each i (<= n)
      - For each rule X → Y Z
        - For each split point k
          Do constant work




  - Total time: |rules|*$n^3$

## Runtime: Practice

- Parsing with the vanilla treebank grammar:




~ 20K Rules

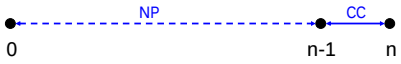
(not an optimized parser!)

Observed exponent: 3.6

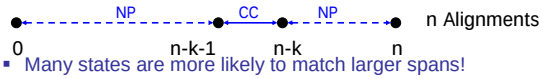
- Why's it worse in practice?
  - Longer sentences "unlock" more of the grammar
  - All kinds of systems issues don't scale

## Rule State Reachability

Example: NP CC •




Example: NP CC NP •




- Many states are more likely to match larger spans!