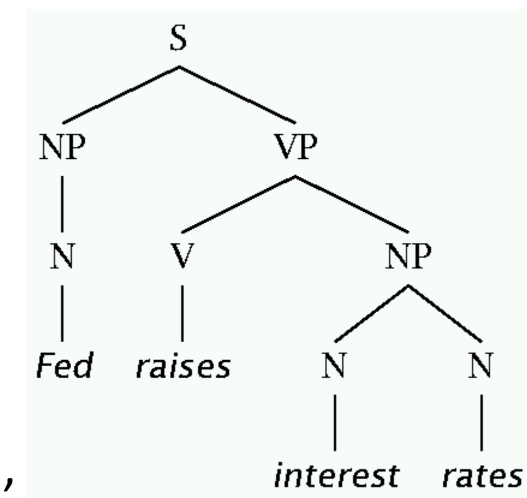
Statistical Natural Language Parsing

Two views of syntactic structure

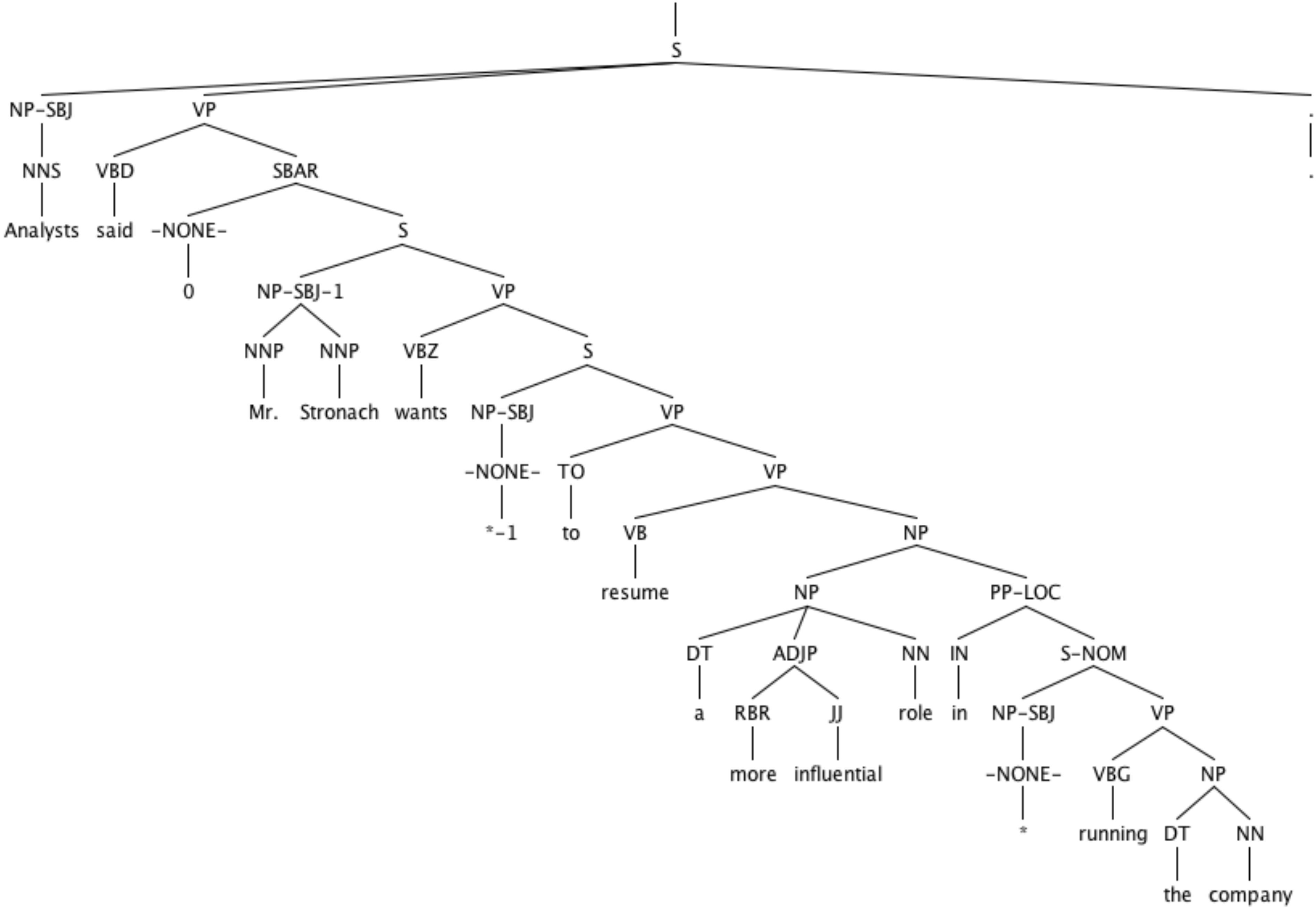
Two views of linguistic structure: 1. Constituency (phrase structure)

- Phrase structure organizes words into nested constituents.
- How do we know what is a constituent? (Not that linguists don't argue about some cases.)
  - Distribution: a constituent behaves as a unit that can appear in different places:
    - John talked [to the children] [about drugs].
    - John talked [about drugs] [to the children].
    - *John talked drugs to the children about
  - Substitution/expansion/pro-forms:
    - I sat [on the box/right on top of the box/there].
  - Coordination, regular internal structure, no intrusion, fragments, semantics, …



Two views of linguistic structure: 1. Constituency (phrase structure)

- Phrase structure organizes words into nested constituents.
- How do we know what is a constituent? (Not that linguists don't argue about some cases.)
  - Distribution: a constituent behaves as a unit that can appear in different places:
    - John talked [to the children] [about drugs].
    - John talked [about drugs] [to the children].
    - *John talked drugs to the children about
  - Substitution/expansion/pro-forms:
    - I sat [on the box/right on top of the box/there].
  - Coordination, regular internal structure, no intrusion, fragments, semantics, …


S
NP-SBJ
VP
.
NNS
VBD
SBAR
.
Analysts
said
-NONE-
S
0
NP-SBJ-1
VP
NNP
NNP
VBZ
S
Mr.
Stronach
wants
NP-SBJ
VP
-NONE-
TO
VP
*-1
to
VB
NP
resume
NP
PP-LOC
DT
ADJP
NN
IN
S-NOM
a
RBR
JJ
role
in
NP-SBJ
VP
more
influential
-NONE-
VBG
NP
*
running
DT
NN
the
company

Headed phrase structure

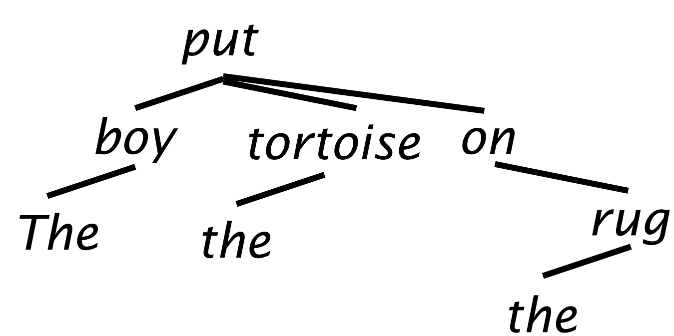
- VP → … VB* …
- NP → … NN* …
- ADJP → … JJ* …
- ADVP → … RB* …

- SBAR(Q) → S|SINV|SQ → … NP VP …

- Plus minor phrase types:
  - QP (quantifier phrase in NP), CONJP (multi word constructions: *as well as*), INTJ (interjections), etc.

Two views of linguistic structure: 2. Dependency structure

- Dependency structure shows which words depend on (modify or are arguments of) which other words.



Two views of linguistic structure:
2. Dependency structure

- Dependency structure shows which words depend on (modify or are arguments of) which other words.

The boy put the tortoise on the rug

Statistical Natural Language Parsing

Two views of syntactic structure

Statistical Natural Language Parsing

Parsing: The rise of data and statistics

Pre 1990 ("Classical") NLP Parsing

- Wrote symbolic grammar (CFG or often richer) and lexicon

S → NP VP	NN → *interest*
NP → (DT) NN	NNS → *rates*
NP → NN NNS	NNS → *raises*
NP → NNP	VBP → *interest*
VP → V NP	VBZ → *rates*

- Used grammar/proof systems to prove parses from words
- This scaled very badly and didn't give coverage. For sentence:

  Fed raises interest rates 0.5% in effort to control inflation

  - Minimal grammar: 36 parses
  - Simple 10 rule grammar: 592 parses
  - Real-size broad-coverage grammar: millions of parses

Classical NLP Parsing: The problem and its solution

- Categorical constraints can be added to grammars to limit unlikely/weird parses for sentences
  - But the attempt make the grammars not robust
    - In traditional systems, commonly 30% of sentences in even an edited text would have *no* parse.
- A less constrained grammar can parse more sentences
  - But simple sentences end up with ever more parses with no way to choose between them
- We need mechanisms that allow us to find the most likely parse(s) for a sentence
  - Statistical parsing lets us work with very loose grammars that admit millions of parses for sentences but still quickly find the best parse(s)

The rise of annotated data: The Penn Treebank

[Marcus et al. 1993, *Computational Linguistics*]

```
( (S
   (NP-SBJ (DT The) (NN move))
   (VP (VBD followed)
     (NP
       (NP (DT a) (NN round))
       (PP (IN of)
         (NP
           (NP (JJ similar) (NNS increases))
           (PP (IN by)
             (NP (JJ other) (NNS lenders)))
           (PP (IN against)
             (NP (NNP Arizona) (JJ real) (NN estate) (NNS loans))))))
     (, ,)
     (S-ADV
       (NP-SBJ (-NONE- *))
       (VP (VBG reflecting)
         (NP
           (NP (DT a) (VBG continuing) (NN decline))
           (PP-LOC (IN in)
             (NP (DT that) (NN market)))))))
   (. .)))
```

The rise of annotated data

- Starting off, building a treebank seems a lot slower and less useful than building a grammar

- But a treebank gives us many things
  - Reusability of the labor
    - Many parsers, POS taggers, etc.
    - Valuable resource for linguistics
  - Broad coverage
  - Frequencies and distributional information
  - A way to evaluate systems

Statistical parsing applications

Statistical parsers are now robust and widely used in larger NLP applications:

- High precision question answering [Pasca and Harabagiu SIGIR 2001]
- Improving biological named entity finding [Finkel et al. JNLPBA 2004]
- Syntactically based sentence compression [Lin and Wilbur 2007]
- Extracting opinions about products [Bloom et al. NAACL 2007]
- Improved interaction in computer games [Gorniak and Roy 2005]
- Helping linguists find data [Resnik et al. BLS 2005]
- Source sentence analysis for machine translation [Xu et al. 2009]
- Relation extraction systems [Fundel et al. *Bioinformatics* 2006]

Statistical Natural Language Parsing

Parsing: The rise of data and statistics

Statistical Natural Language Parsing

An exponential number of attachments

Attachment ambiguities

- A key parsing decision is how we 'attach' various constituents
  - PPs, adverbial or participial phrases, infinitives, coordinations, etc.

The board approved [its acquisition] [by Royal Trustco Ltd.]

[of Toronto]

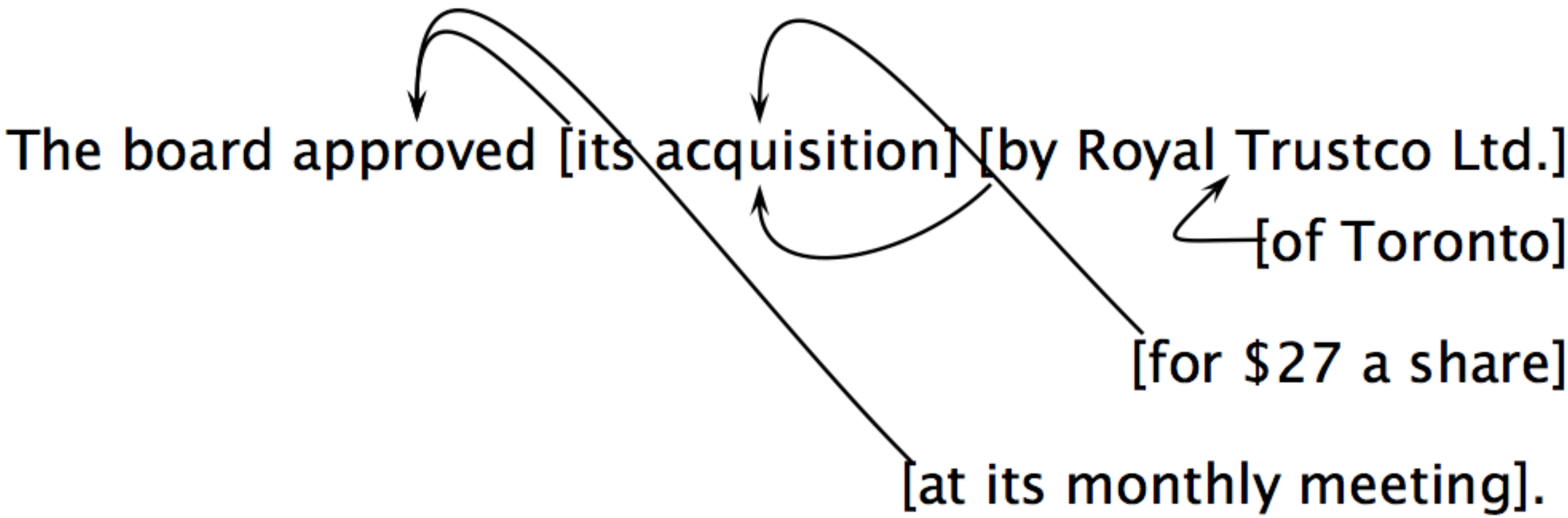
[for $27 a share]

[at its monthly meeting].

- Catalan numbers: $C_n = (2n)!/[(n+1)!n!]$
- An exponentially growing series, which arises in many tree-like contexts:
  - E.g., the number of possible triangulations of a polygon with $n+2$ sides
    - Turns up in triangulation of probabilistic graphical models….

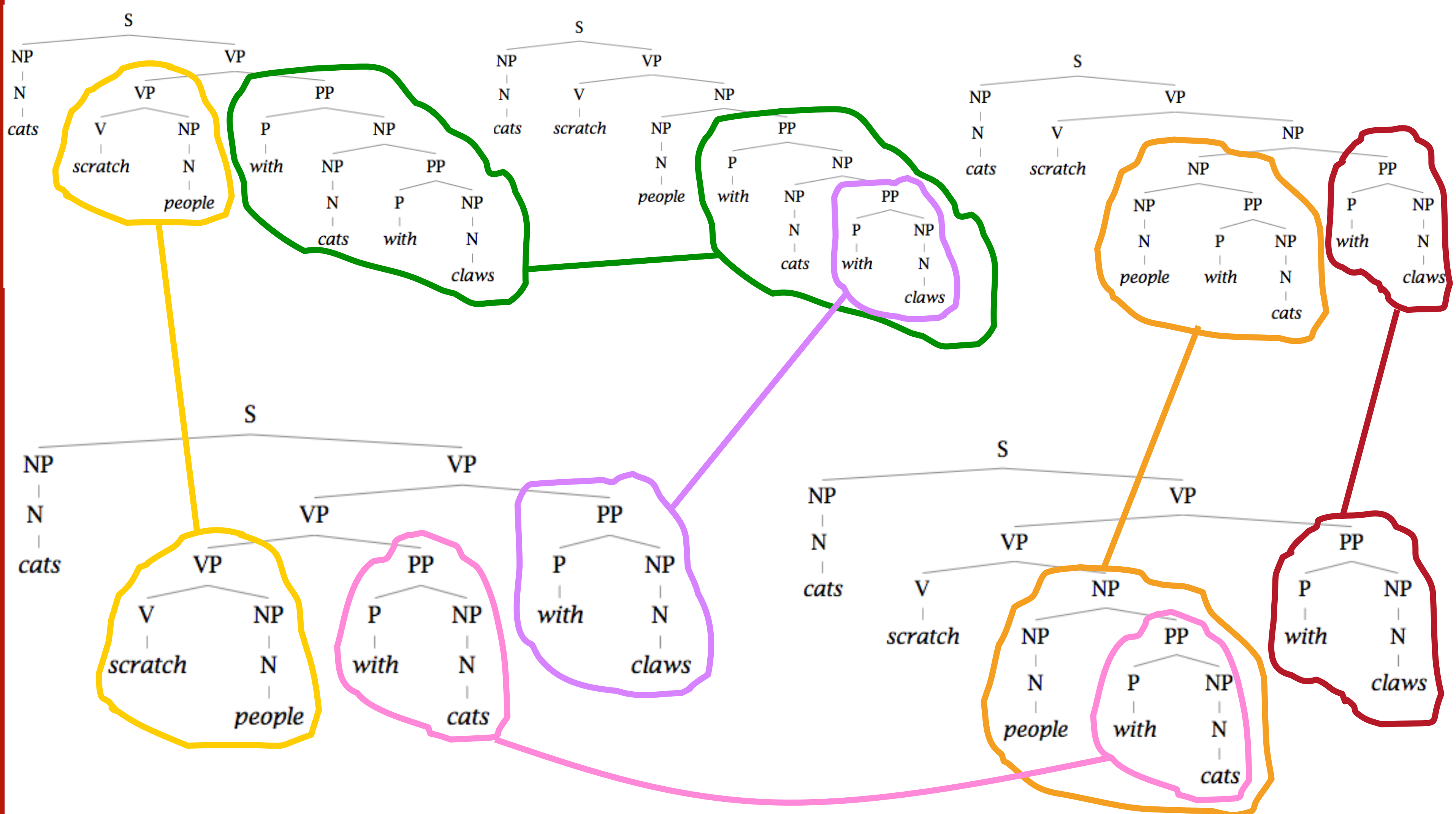
Attachment ambiguities

- A key parsing decision is how we ‘attach’ various constituents
  - PPs, adverbial or participial phrases, infinitives, coordinations, etc.

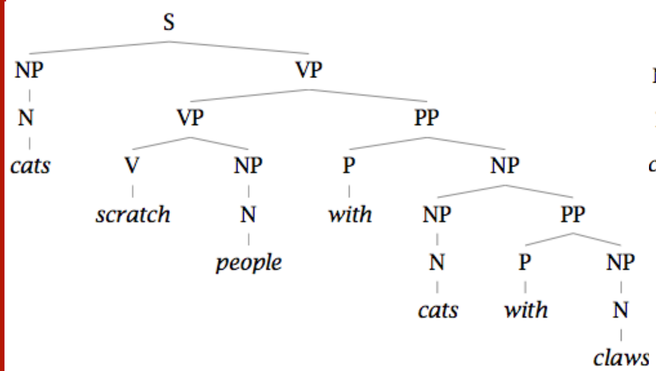


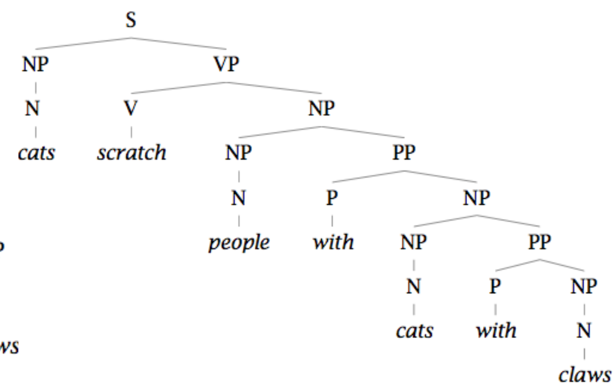
- Catalan numbers: $C_n = (2n)!/[(n+1)!n!]$
- An exponentially growing series, which arises in many tree-like contexts:
  - E.g., the number of possible triangulations of a polygon with $n+2$ sides
    - Turns up in triangulation of probabilistic graphical models….

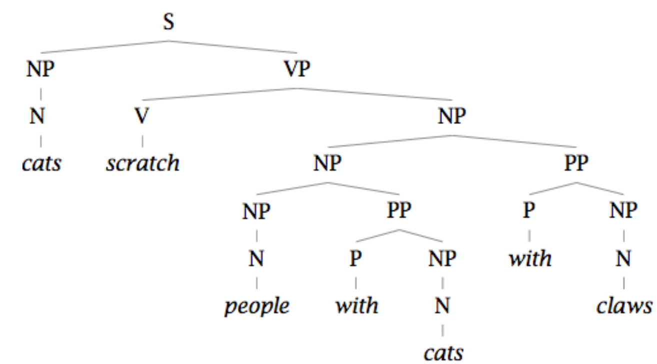
Two problems to solve:
1. Repeated work…

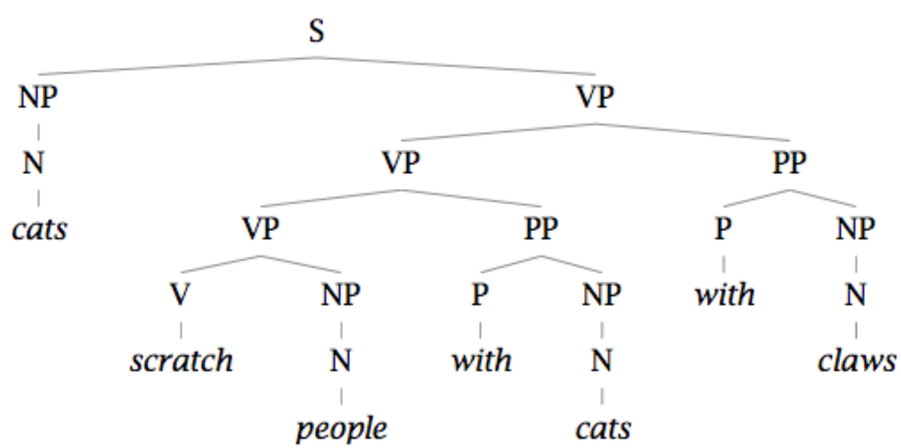


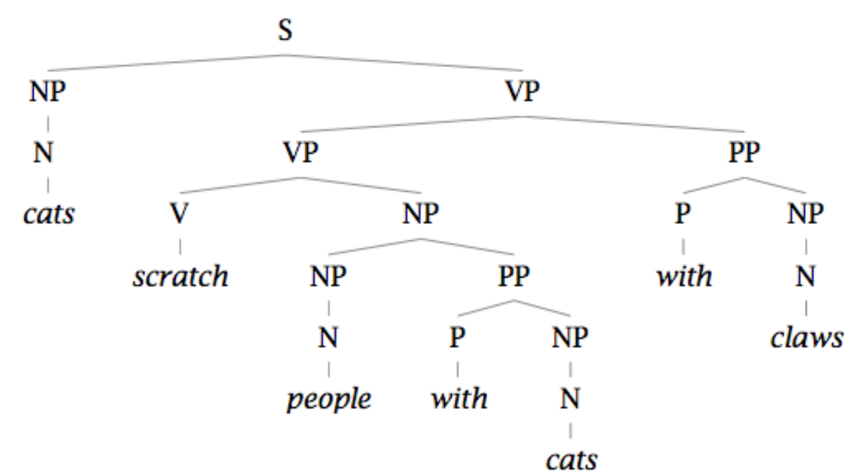
Two problems to solve:
1. Repeated work…











Two problems to solve:
2. Choosing the correct parse

- How do we work out the correct attachment:
  - She saw the man with a telescope
- Is the problem ‘AI complete’? Yes, but …
- Words are good predictors of attachment
    - Even absent full understanding
  - Moscow sent more than 100,000 soldiers into Afghanistan …
  - Sydney Water breached an agreement with NSW Health …
- Our statistical parsers will try to exploit such statistics.

Statistical Natural Language Parsing

An exponential number of attachments