SI485i : NLP

Set 7

Syntax and Parsing

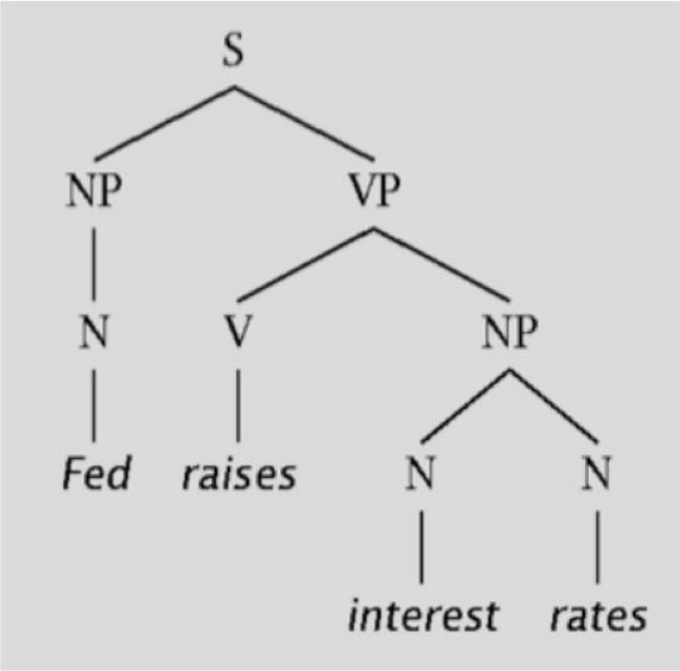
Syntax

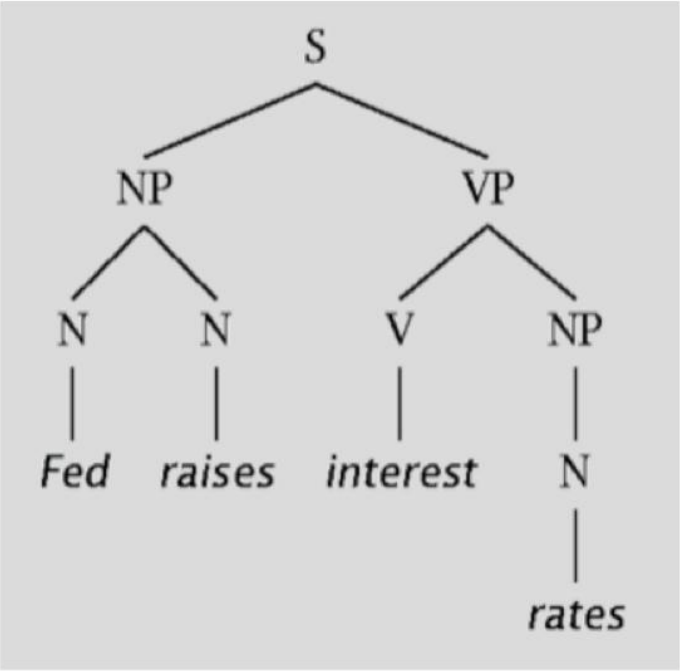
- Grammar, or syntax:
  - The kind of implicit knowledge of your native language that you had mastered by the time you were 3 years old
  - Not the kind of stuff you were later taught in “grammar” school

  - Verbs, nouns, adjectives, etc.
  - Rules, like verbs take noun subjects…

Example

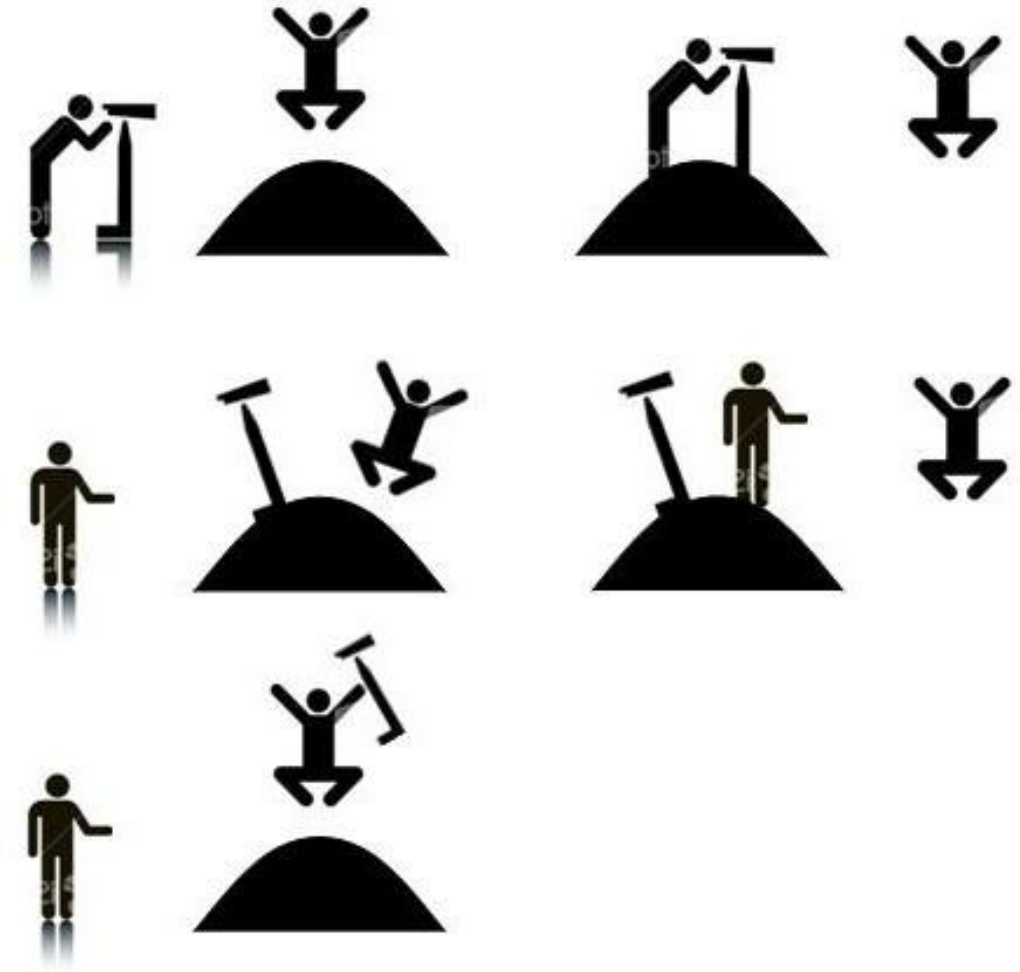
- “Fed raises interest rates”





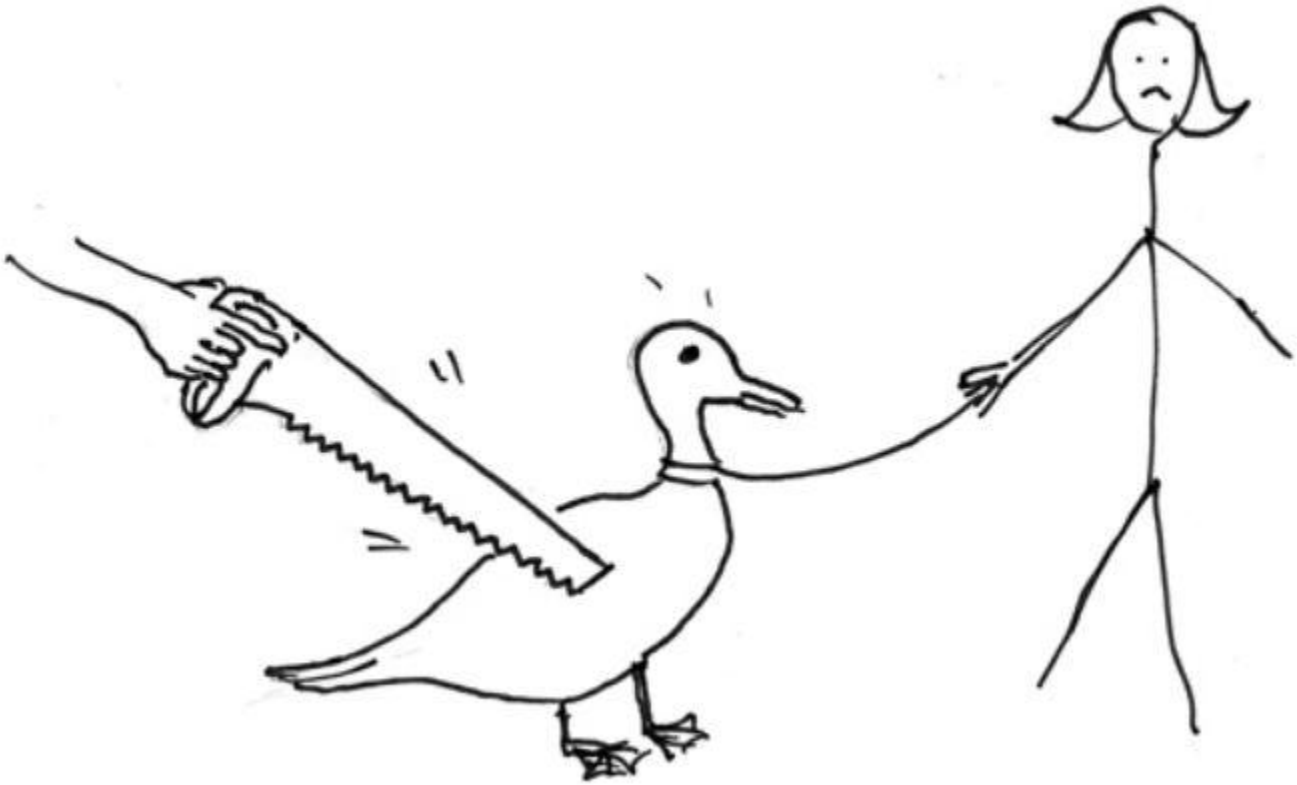
Example 2

"I saw the man on the hill with a telescope."



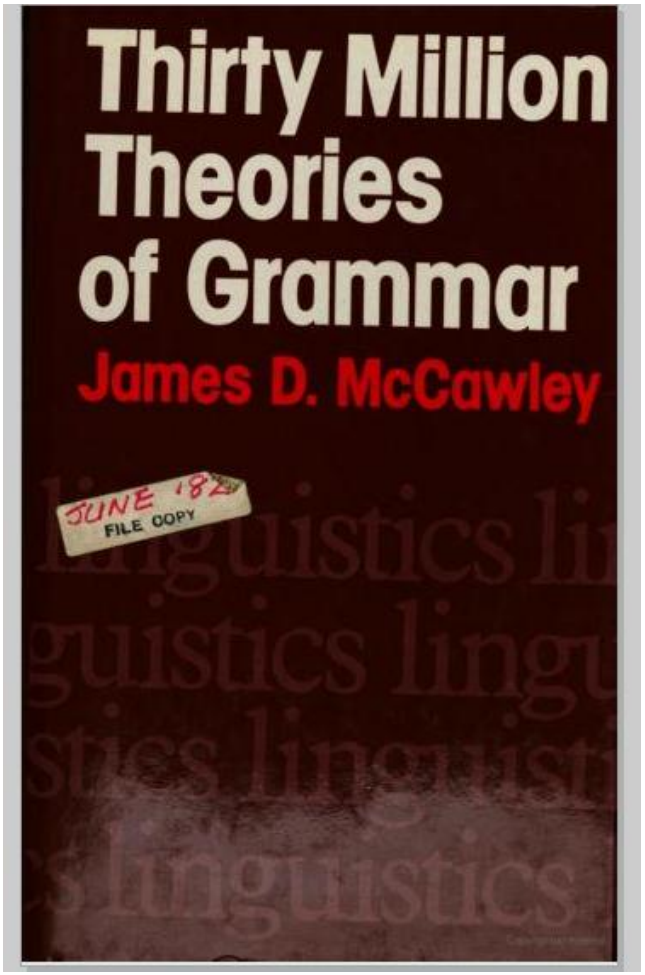
Example 3

- “I saw her duck”



Syntax

- Linguists like to argue
  - Phrase-structure grammars, transformational syntax, X-bar theory, principles and parameters, government and binding, GPSG, HPSG, LFG, relational grammar, minimalism.... And on and on.



Syntax

- Why should you care?

- Email recovery … n-grams only made local decisions.
- Author detection … couldn’t model word structure
- Sentiment … don’t know what sentiment is targeted at

- Many many other applications:
  - Grammar checkers
  - Dialogue management
  - Question answering
  - Information extraction
  - Machine translation

Syntax

- Key notions that we'll cover
  - Part of speech
  - Constituency
  - Ordering
  - Grammatical Relations
- Key formalism
  - Context-free grammars
- Resources
  - Treebanks

Word Classes, or ***Parts of Speech***

- 8 (ish) traditional parts of speech
  - Noun, verb, adjective, preposition, adverb, article, interjection, pronoun, conjunction, etc.

- Lots of debate within linguistics about the number, nature, and universality of these
  - We'll completely ignore this debate.

POS examples

N	noun	*chair, bandwidth, pacing*
V	verb	*study, debate, munch*
ADJ	adjective	*purple, tall, ridiculous*
ADV	adverb	*unfortunately, slowly*
P	preposition	*of, by, to*
PRO	pronoun	*I, me, mine*
DET	determiner	*the, a, that, those*

POS Tagging

- The process of assigning a part-of-speech or lexical class marker to each word in a collection.

WORD	tag
the	**DET**
koala	**N**
put	**V**
the	**DET**
keys	**N**
on	**P**
the	**DET**
table	**N**

POS Tags Vary on Context

refuse

lead

He will refuse to lead.

There is lead in the refuse.

Open and Closed Classes

- **Closed class**: a small fixed membership
  - Usually function words (short common words which play a role in grammar)
- **Open class**: new ones created all the time
  - English has 4: Nouns, Verbs, Adjectives, Adverbs
    - Many languages have these 4, but not all!
  - Nouns are typically where the bulk of the action is with respect to new items

Closed Class Words

Examples:

- prepositions: *on, under, over, …*
- particles: *up, down, on, off, …*
- determiners: *a, an, the, …*
- pronouns: *she, who, I, ..*
- conjunctions: *and, but, or, …*
- auxiliary verbs: *can, may should, …*
- numerals: *one, two, three, third, …*

Open Class Words

- Nouns
  - Proper nouns (Boulder, Granby, Beyoncé, Port-au-Prince)
    - English capitalizes these.
  - Common nouns (the rest)
  - Count nouns and mass nouns
    - Count: have plurals, get counted: goat/goats, one goat, two goats
    - Mass: don't get counted (snow, salt, communism) (*two snows)
- Adverbs: tend to modify things
  - Unfortunately, John walked home extremely slowly yesterday
  - Directional/locative adverbs (here, home, downhill)
  - Degree adverbs (extremely, very, somewhat)
  - Manner adverbs (slowly, slinkily, delicately)
- Verbs
  - In English, have morphological affixes (eat/eats/eaten)

Prepositions from CELEX

of	540,085	through	14,964	worth	1,563	pace	12
in	331,235	after	13,670	toward	1,390	nigh	9
for	142,421	between	13,275	plus	750	re	4
to	125,691	under	9,525	till	686	mid	3
with	124,965	per	6,515	amongst	525	o'er	2
on	109,129	among	5,090	via	351	but	0
at	100,169	within	5,030	amid	222	ere	0
by	77,794	towards	4,700	underneath	164	less	0
from	74,843	above	3,056	versus	113	midst	0
about	38,428	near	2,026	amidst	67	o'	0
than	20,210	off	1,695	sans	20	thru	0
over	18,071	past	1,575	circa	14	vice	0

English Particles

aboard	aside	besides	forward(s)	opposite	through
about	astray	between	home	out	throughout
above	away	beyond	in	outside	together
across	back	by	inside	over	under
ahead	before	close	instead	overhead	underneath
alongside	behind	down	near	past	up
apart	below	east, etc.	off	round	within
around	beneath	eastward(s),etc.	on	since	without

Conjunctions

and	514,946	yet	5,040	considering	174	forasmuch as	0
that	134,773	since	4,843	lest	131	however	0
but	96,889	where	3,952	albeit	104	immediately	0
or	76,563	nor	3,078	providing	96	in as far as	0
as	54,608	once	2,826	whereupon	85	in so far as	0
if	53,917	unless	2,205	seeing	63	inasmuch as	0
when	37,975	why	1,333	directly	26	insomuch as	0
because	23,626	now	1,290	ere	12	insomuch that	0
so	12,933	neither	1,120	notwithstanding	3	like	0
before	10,720	whenever	913	according as	0	neither nor	0
though	10,329	whereas	867	as if	0	now that	0
than	9,511	except	864	as long as	0	only	0
while	8,144	till	686	as though	0	provided that	0
after	7,042	provided	594	both and	0	providing that	0
whether	5,978	whilst	351	but that	0	seeing as	0
for	5,935	suppose	281	but then	0	seeing as how	0
although	5,424	cos	188	but then again	0	seeing that	0
until	5,072	supposing	185	either or	0	without	0

POS: Choosing a Tagset

- There are many potential distinctions we can draw leading to potentially large tagsets
- We need to choose a standard set of tags to work with
- Could pick very coarse tagsets
  - N, V, Adj, Adv.
- More commonly used set is the finer grained, “Penn TreeBank tagset”, 45 tags
  - PRP$, WRB, WP$, VBG
- Even more fine-grained tagsets exist

Penn TreeBank POS Tagset

Tag	Description	Example	Tag	Description	Example
CC	coordin. conjunction	*and, but, or*	SYM	symbol	+,%, &
CD	cardinal number	*one, two, three*	TO	"to"	*to*
DT	determiner	*a, the*	UH	interjection	*ah, oops*
EX	existential 'there'	*there*	VB	verb, base form	*eat*
FW	foreign word	*mea culpa*	VBD	verb, past tense	*ate*
IN	preposition/sub-conj	*of, in, by*	VBG	verb, gerund	*eating*
JJ	adjective	*yellow*	VBN	verb, past participle	*eaten*
JJR	adj., comparative	*bigger*	VBP	verb, non-3sg pres	*eat*
JJS	adj., superlative	*wildest*	VBZ	verb, 3sg pres	*eats*
LS	list item marker	*1, 2, One*	WDT	wh-determiner	*which, that*
MD	modal	*can, should*	WP	wh-pronoun	*what, who*
NN	noun, sing. or mass	*llama*	WP$	possessive wh-	*whose*
NNS	noun, plural	*llamas*	WRB	wh-adverb	*how, where*
NNP	proper noun, singular	*IBM*	$	dollar sign	*$*
NNPS	proper noun, plural	*Carolinas*	#	pound sign	#
PDT	predeterminer	*all, both*	"	left quote	' or "
POS	possessive ending	*'s*	"	right quote	' or "
PRP	personal pronoun	*I, you, he*	(	left parenthesis	[, (, {, <
PRP$	possessive pronoun	*your, one's*	)	right parenthesis	],), }, >
RB	adverb	*quickly, never*	,	comma	,
RBR	adverb, comparative	*faster*	.	sentence-final punc	. ! ?
RBS	adverb, superlative	*fastest*	:	mid-sentence punc	: ; ... – -
RP	particle	*up, off*			

Worth Repeating

- Words often have more than one POS
  - The *back* door = JJ
  - On my *back* = NN
  - Win the voters *back* = RB
  - Promised to *back* the bill = VB

- Part of the challenge of Parsing is to determine the POS tag for a particular instance of a word. This can change the entire parse tree.

These examples from Dekang Lin

Word Classes and Constituency

- Words can be part of a word class.
- But words can also join others to form groups.
  - Often called *phrases*
  - Groups of words that share properties is *constituency*

Constituency

- Groups of words within utterances act as single units
- These units form coherent classes that can be shown to behave in similar ways
  - With respect to their internal structure
  - And with respect to other units in the language

Constituency

- Internal structure
  - Manipulate the phrase in some way, is it consistent across all constituent members?
- External behavior
  - What other constituents does this one commonly associate with (follows or precedes)?
    - For example, noun phrases can come before verbs

Constituency

- For example, it makes sense to the say that the following are all ***noun phrases*** in English...

Harry the Horse	a high-class spot such as Mindy's
the Broadway coppers	the reason he comes into the Hot Box
they	three parties from Brooklyn

- Why? One piece of evidence is that they can all precede verbs.
  - "external evidence"

Grammars and Constituency

- Of course, there's nothing easy or obvious about how we come up with right set of constituents and the rules that govern how they combine...
- That's why there are so many different theories of grammar and competing analyses of the same data.
- The approach to grammar, and the analyses, adopted here are very generic (and don't correspond to any modern linguistic theory of grammar).

Context-Free Grammars

- Context-free grammars (CFGs)
  - Phrase structure grammars
  - Backus-Naur form
- Consist of
  - Rules
  - Terminals
  - Non-terminals

Context-Free Grammars

- Terminals
  - We'll take these to be words (for now)
- Non-Terminals
  - The constituents in a language
    - Like noun phrase, verb phrase and sentence
- Rules
  - Rules consist of a single non-terminal on the left and any number of terminals and non-terminals on the right.

Some NP Rules

- Here are some rules for our noun phrases

$$
\begin{aligned}
NP &\rightarrow Det\ Nominal \\
NP &\rightarrow ProperNoun \\
Nominal &\rightarrow Noun \mid Nominal\ Noun
\end{aligned}
$$

- Together, these describe two kinds of NPs.
  - One that consists of a determiner followed by a nominal
  - And another that says that proper names are NPs.
  - The third rule illustrates two things
    - An explicit disjunction (Two kinds of nominals)
    - A recursive definition (Same non-terminal on the right and left)

Example Grammar

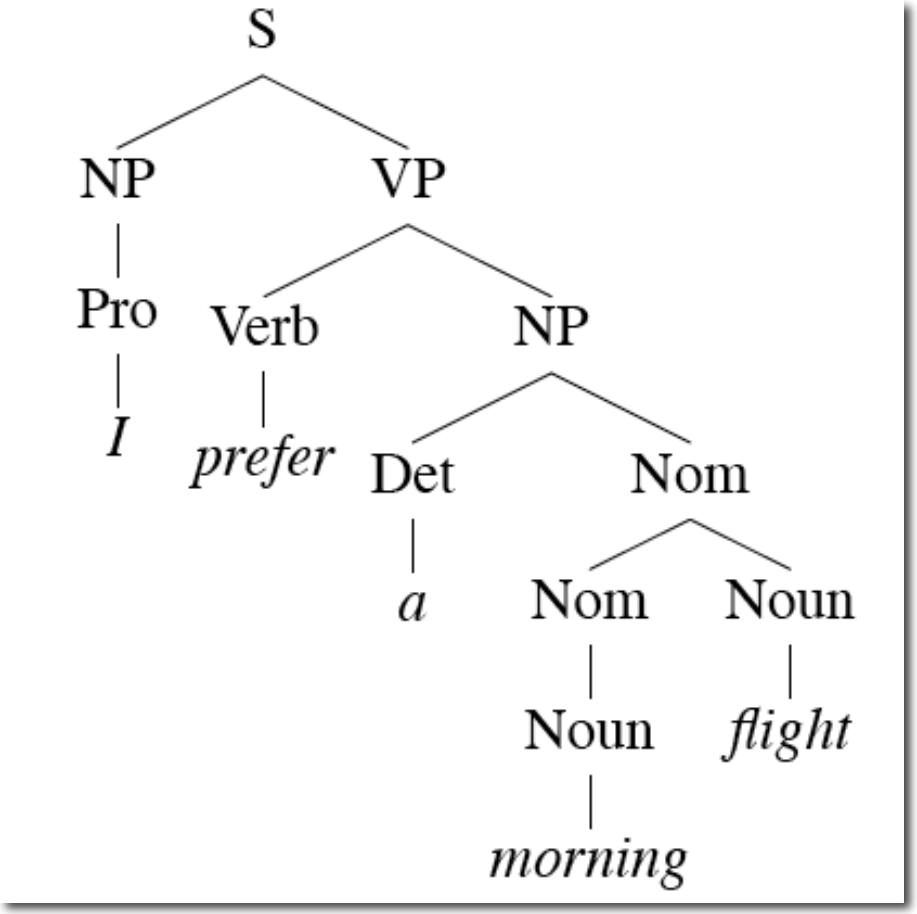
Grammar Rules			Examples
S	$\rightarrow$	*NP VP*	I + want a morning flight
NP	$\rightarrow$	*Pronoun*	I
	|	*Proper-Noun*	Los Angeles
	|	*Det Nominal*	a + flight
Nominal	$\rightarrow$	*Nominal Noun*	morning + flight
	|	*Noun*	flights
VP	$\rightarrow$	*Verb*	do
	|	*Verb NP*	want + a flight
	|	*Verb NP PP*	leave + Boston + in the morning
	|	*Verb PP*	leaving + on Thursday
PP	$\rightarrow$	*Preposition NP*	from + Los Angeles

Generativity

- As with FSAs and FSTs, you can view these rules as either analysis or synthesis engines
  - Generate strings in the language
  - Reject strings not in the language
  - Impose structures (trees) on strings in the language

Derivations

- A *derivation* is a sequence of rules applied to a string that *accounts* for that string
  - Covers all the elements in the string
  - Covers only the elements in the string



Definition

- Formally, a CFG (*you should know this already*)

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 $A \rightarrow \beta$,
	where A is a non-terminal,
	β is a string of symbols from the infinite set of strings $(\Sigma \cup N)*$
S	a designated **start symbol**

Parsing

- Parsing is the process of taking a string and a grammar and returning parse tree(s) for that string

Sentence Types

- Declaratives: *A plane left.*

  $S \rightarrow NP\ VP$

- Imperatives: *Leave!*

  $S \rightarrow VP$

- Yes-No Questions: *Did the plane leave?*

  $S \rightarrow Aux\ NP\ VP$

- WH Questions: *When did the plane leave?*

  $S \rightarrow WH\text{-}NP\ Aux\ NP\ VP$

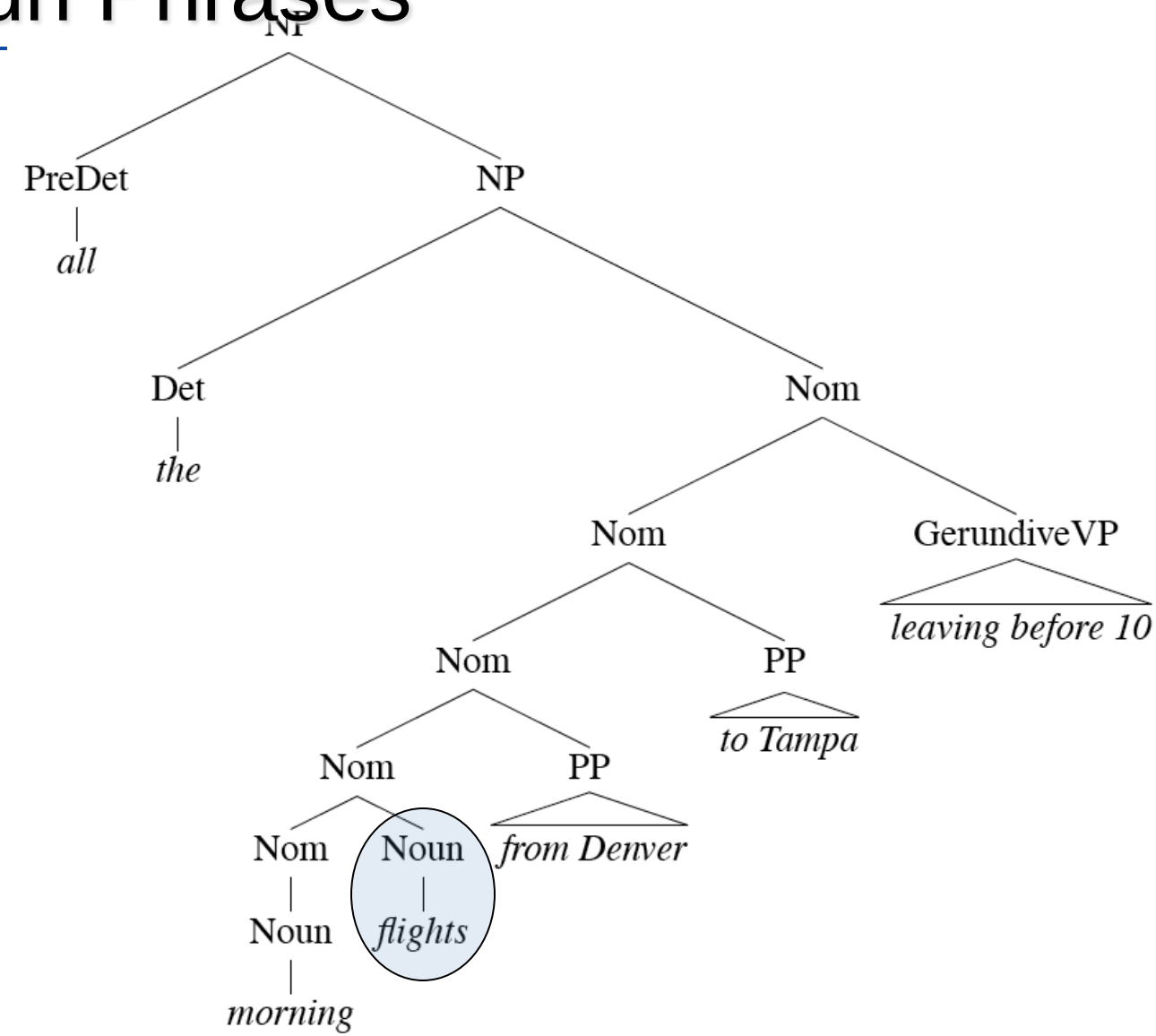
Noun Phrases

- Let's consider the following rule in more detail...

$$NP \rightarrow Det\ Nominal$$

- Most of the complexity of English noun phrases is hidden inside this one rule.

Noun Phrases



Determiners

- Noun phrases can start with determiners...
- Determiners can be
  - Simple lexical items: *the, this, a, an*, etc.
    - A car
  - Or simple possessives
    - John's car
  - Or complex recursive versions of that
    - John's sister's husband's son's car

Nominals

- Contains the main noun and any pre- and post-modifiers of the head.
  - Pre-
    - Quantifiers, cardinals, ordinals...
      - Three cars
    - Adjectives and Aps
      - large cars
    - Ordering constraints
      - Three large cars
      - ?large three cars

Postmodifiers

- Three kinds
  - Prepositional phrases
    - From Seattle
  - Non-finite clauses
    - Arriving before noon
  - Relative clauses
    - That serve breakfast
- Some general (recursive) rules
  - *Nominal* $\rightarrow$ *Nominal PP*
  - *Nominal* $\rightarrow$ *Nominal GerundVP*
  - *Nominal* $\rightarrow$ *Nominal RelClause*

Agreement

- By ***agreement***, we have in mind constraints that hold among various constituents that take part in a rule or set of rules
- For example, in English, determiners and the head nouns in NPs have to agree in their number.

This flight

Those flights

*This flights

*Those flight

Verb Phrases

- English *VP*s consist of a head verb along with 0 or more following constituents which we'll call *arguments*.

$$
\begin{array}{lcll}
VP & \rightarrow & Verb & \text{disappear} \\
VP & \rightarrow & Verb\ NP & \text{prefer a morning flight} \\
VP & \rightarrow & Verb\ \ NP\ \ PP & \text{leave Boston in the morning} \\
VP & \rightarrow & Verb\ \ PP & \text{leaving on Thursday}
\end{array}
$$

Subcategorization

- Not all verbs are allowed to participate in all those VP rules.
- We can *subcategorize* the verbs in a language according to the sets of VP rules that they participate in.
- This is just a variation on the traditional notion of transitive/intransitive.
- Modern grammars may have 100s of such classes

Subcategorization

- Sneeze: John sneezed
- Find: Please find [a flight to NY]$_{NP}$
- Give: Give [me]$_{NP}$[a cheaper fare]$_{NP}$
- Help: Can you help [me]$_{NP}$[with a flight]$_{PP}$
- Prefer: I prefer [to leave earlier]$_{TO\text{-}VP}$
- Told: I was told [United has a flight]$_{S}$
- …

Programming Analogy

- It may help to view things this way
  - Verbs are functions or methods
  - The arguments they take (subcat frames) they participate in specify the number, position and type of the arguments they take...
    - That is, just like the formal parameters to a method.

Subcategorization

- *John sneezed the book
- *I prefer United has a flight
- *Give with a flight

- As with agreement phenomena, we need a way to formally express these facts

Why?

- Right now, the various rules for VPs *overgenerate*.
  - They permit the presence of strings containing verbs and arguments that don't go together
  - For example
  - VP -> V NP therefore

    Sneezed the book is a VP since "sneeze" is a verb and "the book" is a valid NP

Possible CFG Solution

- Possible solution for agreement.
- Can use the same trick for all the verb/VP classes.

- SgS -> SgNP SgVP
- PlS -> PlNp PlVP
- SgNP -> SgDet SgNom
- PlNP -> PlDet PlNom
- PlVP -> PlV NP
- SgVP ->SgV Np
- …

CFG Solution for Agreement

- It works and stays within the power of CFGs
- But it is ugly
- It doesn’t scale all that well because the interaction among constraints explodes the number of rules in our grammar.

The Ugly Reality

- CFGs appear to be just about what we need to account for a lot of basic syntactic structure in English.
- But there are problems
  - That can be dealt with adequately, although not elegantly, by staying within the CFG framework.
- There are simpler, more elegant, solutions that take us out of the CFG framework (beyond its formal power)
  - LFG, HPSG, Construction grammar, XTAG, etc.
  - Chapter 15 explores the unification approach in more detail

What do we as computer scientists?

- Stop trying to hardcode all possibilities.
- Find a bunch of sentences and parse them by hand.
- Build a *probabilistic* CFG over the parse trees, implicitly capturing these nasty constraints with probabilities.

Treebanks

- Treebanks are corpora in which each sentence has been paired with a parse tree (presumably the right one).
- These are generally created
  - By first parsing the collection with an automatic parser
  - And then having human annotators correct each parse as necessary.
- This generally requires detailed annotation guidelines that provide a POS tagset, a grammar and instructions for how to deal with particular grammatical constructions.

Penn Treebank

- Penn TreeBank is a widely used treebank.

Most well known part is the Wall Street Journal section of the Penn TreeBank.

- 1 M words from the 1987-1989 Wall Street Journal.

```
( (S (`` ``)
    (S-TPC-2
      (NP-SBJ-1 (PRP We) )
      (VP (MD would)
        (VP (VB have)
          (S
            (NP-SBJ (-NONE- *-1) )
            (VP (TO to)
              (VP (VB wait)
                (SBAR-TMP (IN until)
                  (S
                    (NP-SBJ (PRP we) )
                    (VP (VBP have)
                      (VP (VBN collected)
                        (PP-CLR (IN on)
                          (NP (DT those)(NNS assets))))))))))))
    (, ,) (`` ``)
    (NP-SBJ (PRP he) )
    (VP (VBD said)
      (S (-NONE- *T*-2) ))
    (. .) ))
```

Treebank Grammars

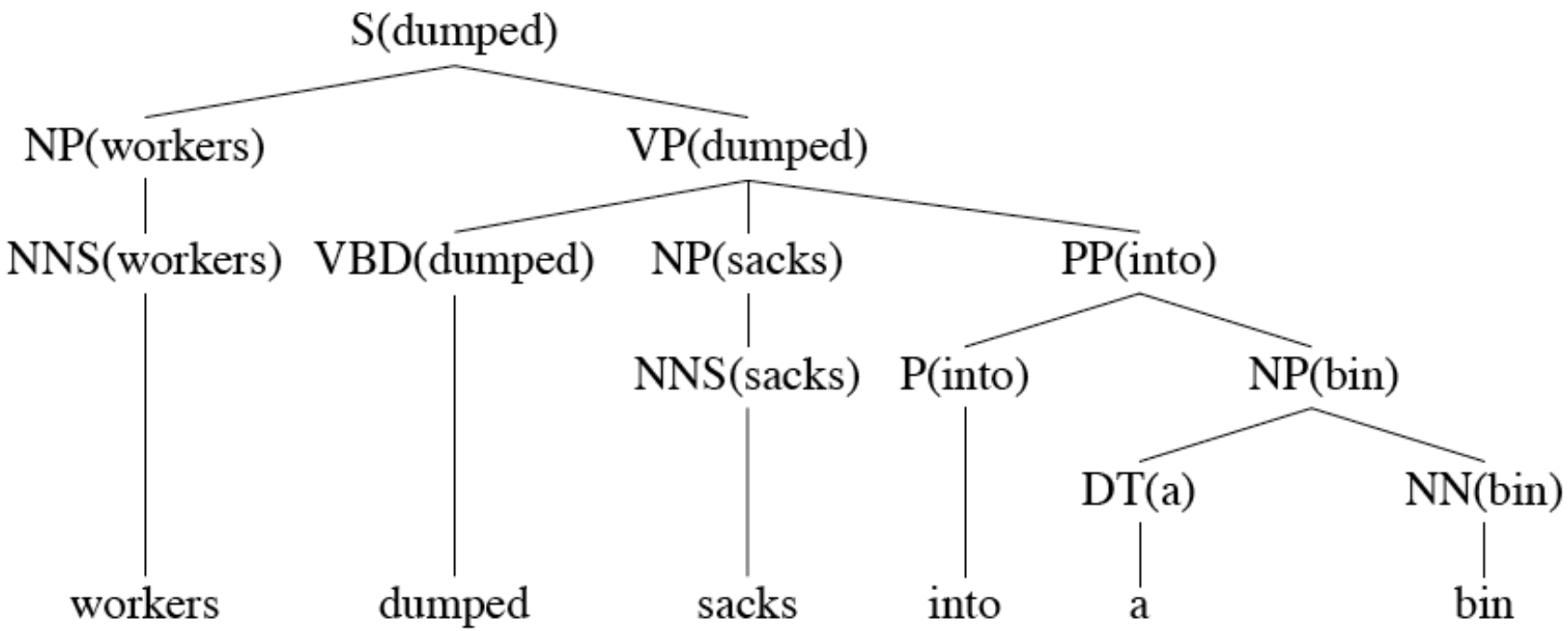
- Treebanks implicitly define a grammar for the language covered in the treebank.
- Simply take the local rules that make up the sub-trees in all the trees in the collection and you have a grammar
  - The WSJ section gives us about 12k rules if you do this
- Not complete, but if you have decent size corpus, you'll have a grammar with decent coverage.

Treebank Grammars

- Such grammars tend to be very flat due to the fact that they tend to avoid recursion.
  - To ease the annotators burden, among things
- For example, the Penn Treebank has ~4500 different rules for VPs. Among them...

```
VP → VBD PP
VP → VBD PP PP
VP → VBD PP PP PP
VP → VBD PP PP PP PP
```

Lexically Decorated Tree



Treebank Uses

- Treebanks are particularly critical to the development of statistical parsers
  - Chapter 14
- Also valuable to *Corpus Linguistics*
  - Investigating the empirical details of various constructions in a given language