Parsing

(These slides are modified from Dan Jurafsky's slides.)

Today

- Formal Grammars
  - Context-free grammar
  - Grammars for English
  - Treebanks
  - Dependency grammars

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Syntax

- By grammar, or syntax, we have in mind the kind of implicit knowledge of your native language that you had mastered by the time you were 3 years old without explicit instruction
- Not the kind of stuff you were later taught in "grammar" school

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Syntax

- Why should you care?
- Grammars (and parsing) are key components in many applications
  - Grammar checkers
  - Dialogue management
  - Question answering
  - Information extraction
  - Machine translation

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Syntax

- Key notions that we'll cover
  - Constituency
  - Grammatical relations and Dependency
    - Heads
- Key formalism
  - Context-free grammars
- Resources
  - Treebanks

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Constituency

- A sequence of words that acts as a single unit
  - Noun phrases
  - Verb phrases
- These units form coherent classes that behave in similar ways
  - For example, we can say that noun phrases can come before verbs

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Constituency

- For example, 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

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Context-Free Grammars

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

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Context-Free Grammars

- Terminals
  - words
- Non-Terminals
  - The constituents in a language
    - Such as noun phrases, verb phrases and sentences
- Rules
  - Rules are equations that consist of a single non-terminal on the left and any number of terminals and non-terminals on the right.

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Some NP Rules

- Here are some rules for our noun phrases

$$NP \rightarrow Det\ Nominal$$
$$NP \rightarrow ProperNoun$$
$$Nominal \rightarrow Noun \mid Nominal\ Noun$$

- 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
    - A recursive definition

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L0 Grammar

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

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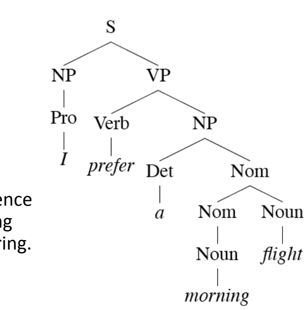
Derivations

A "***derivation***" is a sequence of rules applied to a string that *accounts* for that string.



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Definition

- More formally, a CFG consists of

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**

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Parsing

- Parsing is the process of taking a string and a grammar and returning a (or multiple) parse tree(s) for that string
- It is completely analogous to running a finite-state transducer with a tape
  - It's just more powerful ➔ there are languages we can capture with CFGs that we can't capture with finite-state machines.

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An English Grammar Fragment

- Sentences
- Noun phrases
  - Agreement
- Verb phrases
  - Subcategorization

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Sentence Types

- Declaratives: *A plane left.*

  S → NP VP
- Imperatives: *Leave!*

  S → VP
- Yes-No Questions: *Did the plane leave?*

  S → Aux NP VP
- WH Questions: *When did the plane leave?*

  S → WH-NP Aux NP VP

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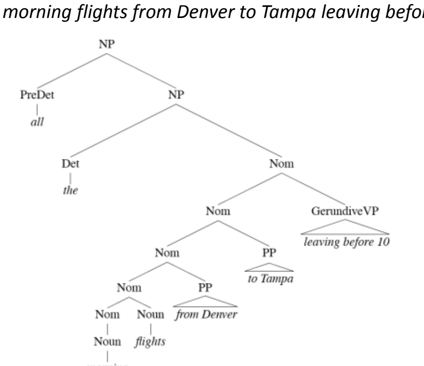
All the morning flights from Denver to Tampa leaving before 10



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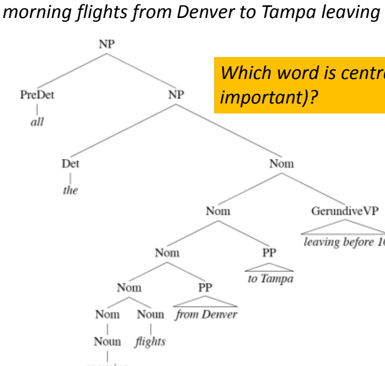
All the morning flights from Denver to Tampa leaving before 10

Which word is central (most important)?



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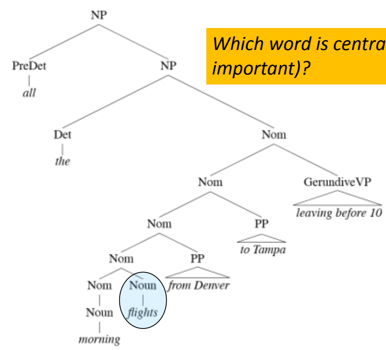
All the morning flights from Denver to Tampa leaving before 10



Which word is central (most important)?

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NP Structure

➔ *All the morning flights from Denver to Tampa leaving before 10*

- Clearly this NP is really about *flights*. That's the central critical noun in this NP. Such word is called as the ***head***.
- We can dissect this kind of NP into the stuff that can come before the head, and the stuff that can come after it.

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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

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Nominals

- Contains the head 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

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Postmodifiers

- Three kinds
  - **Prepositional phrases**
    - Flights ***from Seattle***
  - **Non-finite clauses**
    - Flights ***arriving before noon***
  - **Relative clauses**
    - Flights ***that serve breakfast***
- Same general (recursive) rule to handle these
  - *Nominal → Nominal PP*
  - *Nominal → Nominal GerundVP*
  - *Nominal → Nominal RelClause*

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Agreement

- Constraints that hold among various constituents.
- For example, in English, determiners and the head nouns in NPs have to agree in their number.
- Which of the following cannot be parsed by the rule ***NP → Det Nominal*** ?

(O) This flight	(X) This flights
(O) Those flights	(X) Those flight

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Agreement

- Constraints that hold among various constituents.
- For example, in English, determiners and the head nouns in NPs have to agree in their number.

- Which of the following cannot be parsed by the rule

NP → Det Nominal **?**

➔ This rule does not handle agreement! (The rule does not detect whether the agreement is correct or not.)

(O) This flight	(X) This flights
(O) Those flights	(X) Those flight

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Problem

- Our earlier NP rules are clearly deficient since they don't capture the agreement constraint
  - *NP → Det Nominal*
    - Accepts, and assigns correct structures, to grammatical examples (*this flight*)
    - But its also happy with incorrect examples (*these flight)
  - Such a rule is said to ***overgenerate***.
  - We'll come back to this in a bit

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Verb Phrases

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

VP	→	*Verb*	disappear
VP	→	*Verb NP*	prefer a morning flight
VP	→	*Verb NP PP*	leave Boston in the morning
VP	→	*Verb PP*	leaving on Thursday

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Subcategorization

- But, even though there are many valid VP rules in English, 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 a modern take on the traditional notion of transitive/intransitive.
- Modern grammars may have 100s or such classes.

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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]$_{S}$
- …

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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 the constraints!

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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

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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
- ...

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CFG Solution for Agreement

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

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To conclude

- CFGs are simple and capture a lot of basic syntactic structure in English.
- But there are problems
  - Don't handle "agreement" and "subcategorization"
  - Overgenerate!
- Advanced grammars
  - LFG
  - HPSG
  - Construction grammar
  - XTAG

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Treebanks

- Treebanks are corpora in which each sentence has been paired with a parse tree (presumably the right one).

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Penn Treebank

- Penn TreeBank is a widely used treebank.

▪Most well known 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) ))
    (. .) ))
```

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Treebank Grammars

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

$$VP \rightarrow VBD\ PP$$
$$VP \rightarrow VBD\ PP\ PP$$
$$VP \rightarrow VBD\ PP\ PP\ PP$$
$$VP \rightarrow VBD\ PP\ PP\ PP\ PP$$

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Heads in Trees

- Finding heads in treebank trees is a task that arises frequently in many applications.
  - Particularly important in statistical parsing
- We can visualize this task by annotating the nodes of a parse tree with the heads of each corresponding node.

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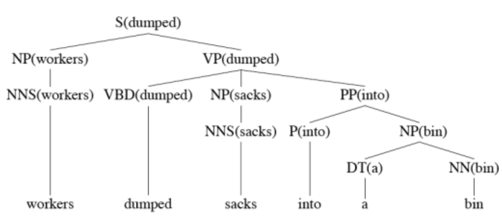
Lexically Decorated Tree



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Head Finding

- The standard way to do head finding is to use a simple set of tree traversal rules specific to each non-terminal in the grammar.

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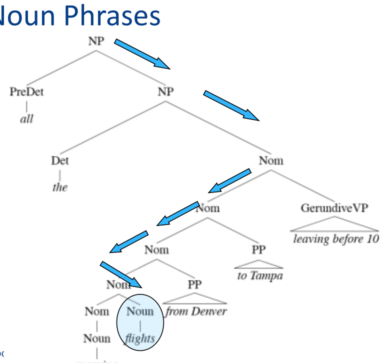
Noun Phrases



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Treebank Uses

- Treebanks (and headfinding) 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

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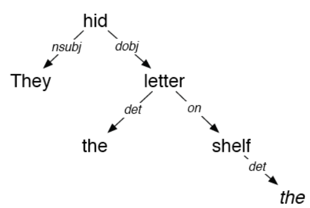
Dependency Grammars

- In CFG-style phrase-structure grammars the main focus is on ***constituents***.
- But it turns out you can get a lot done with just binary relations among the words in an utterance.
- In a **dependency grammar** framework, a parse is a tree where
  - the nodes stand for the words in an utterance
  - The links between the words represent dependency relations between pairs of words.
    - Relations may be typed (labeled), or not.

Dependency Relations

Argument Dependencies	Description
nsubj	nominal subject
csubj	clausal subject
dobj	direct object
iobj	indirect object
pobj	object of preposition
Modifier Dependencies	**Description**
tmod	temporal modifier
appos	appositional modifier
det	determiner
prep	prepositional modifier

Dependency Parse



They hid the letter on the shelf

Dependency Parsing

- The dependency approach has a number of advantages over full phrase-structure parsing.
  - Deals well with free word order languages where the constituent structure is quite fluid
  - Parsing is much faster than CFG-bases parsers
  - Dependency structure often captures the syntactic relations needed by later applications
    - CFG-based approaches often extract this same information from trees anyway.

Dependency Parsing

- There are two modern approaches to dependency parsing
  - Optimization-based approaches that search a space of trees for the tree that *best* matches some criteria
  - Shift-reduce approaches that greedily take actions based on the current word and state.

Summary

- Context-free grammars can be used to model various facts about the syntax of a language.
- When paired with parsers, such grammars constitute a critical component in many applications.
- Constituency is a key phenomena easily captured with CFG rules.
  - But agreement and subcategorization do pose significant problems
- Treebanks pair sentences in corpus with their corresponding trees.