6.863J Natural Language Processing
Lecture 13: Featured attraction

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The Menu Bar

- Administrivia:
  - Lab 3b out later today - Weds; due after vacation – April 5

Agenda:

Fillers & Gaps; I shrank the grammar!

Features & feature grammars

Job 1: writing grammar rules

- Three sorts of examples to handle:

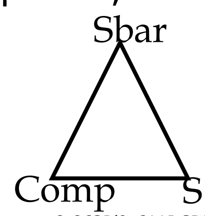
1. Simple declarative sentences
   Poirot solved the case
   Poirot thought
   Poirot sent the solution to the police
   Poirot believed the detectives were incompetent
2. Auxiliary verb sentences
   P. may have been solving the case
3. Unbounded dependencies: Questions and relative clauses
   Which case did Poirot solve
   The solution that P. sent to the police solved the case

Want to block:

- *do not* overgenerate
  **Poirot solved; *P. may solved the case;*
  **Which solution did P. send which solution to the police?*

Preliminaries: phrase names

- *I said that ice-cream was on the table*
  I said ice-cream was on the table
- What is the structure here?
- Existence of *Complementizer* (*COMP*) before Sentence phrase, forming an "Sbar phrase" (S):



Sbar→(Comp) S

Sbar= Comp S

- The *Comp* item can be *that, which, …*- or a displaced phrase
- Also present in 'root' (top level) sentences (*I like ice-cream*) but usually we don't 'hear' it (unless it's filled by question or focus phrase)
- Serves as 'landing site' for fillers
- In embedded sentences, in English, the *Comp* is optional
- If *Comp* is filled – then that blocks things:
  Who (F) do I know that John likes (G)

Filler-gap examples

Example	Ordinary Sentence	Filler-gap analog
Wh-question	*Mary saw Bill*	*Who (F) did Mary see (G)?*
Topicalization	*John hates beans*	*Beans (F) John hates (G)*
Tough-movement	*It is hard to please John*	*John (F) is hard to please (G)*
Relative clauses	*John likes the guy*	*The guy (F) that John likes (G)*

Fillers and gaps, redux

- Fillers and Gaps summary: F, G
- Filler is the *displaced phrase*
- Gap is a *phonological null* (unpronounced) *empty category* (though it can have secondary phonological consequences:
  - *This student (F) you want (G) to solve the problem* blocks contraction between *want* and *to* into *wanna*
  - ? *This student you wanna solve the problem*
- F-G relation represents displacement from canonical semantic argument position
- Many examples of this in natural language

Fillers and gaps

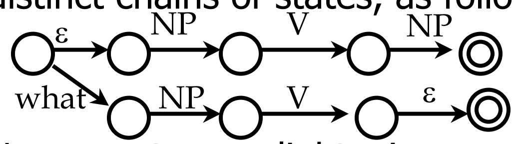
- Since 'gap' is NP going to empty string, we could just add rule, NP$\rightarrow\varepsilon$
- But this will *overgenerate*- how?
- We need a way to distinguish between
  - What did John eat
  - Did John eat
- How did this work in the FSA case?

So, what do we need

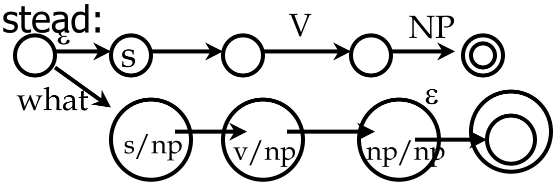
- A rule to expand NP as the empty symbol; that's easy enough: NP$\rightarrow\varepsilon$
- A way to make sure that NP is expanded as empty symbol iff there is a gap (in the right place) before/after it
- A way to link the filler and the gap
- We can do all this by futzing with the rules: *Generalized Phrase Structure Grammar (GPSG)*

"State-splitting" to remember wh seen (but not heard) – need new states (cf. vowel harmony, etc.)

- We could encode the two possible routes by distinct chains of states, as follows:



- Names not very elightening, so will use this instead:



So we have to add rules with new nonterminals to 'name' states…

- S/NP $\rightarrow$ NP VP/NP
- VP/NP $\rightarrow$ V NP/NP
- NP/NP$\rightarrow\varepsilon$
- We haven't put the auxiliary verb stuff in…
- Note the 'chain' of slashed rules in the final structure
- What happens computationally?

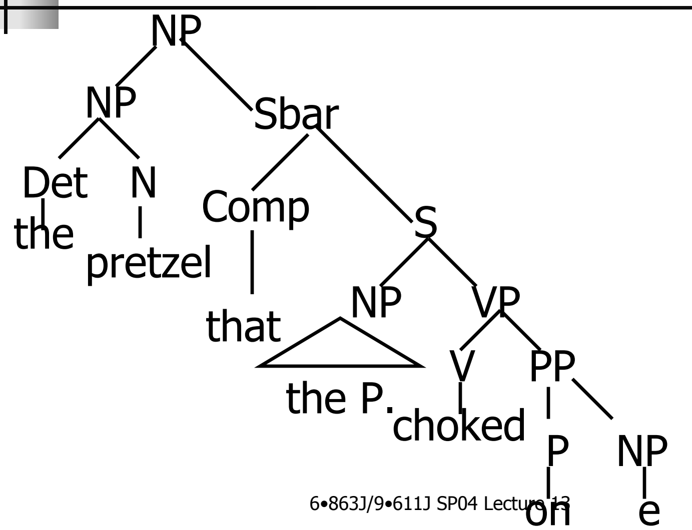
Actual 'marks' in the literature

- Called a 'slash category'
- Ordinary category: Sbar, VP, NP
- Slash category: Sbar/NP, VP/NP, NP/NP
- "X/Y" is ONE atomic nonterminal
- Interpret as: Subtree X is missing a Y (expanded as e) underneath
- Example: Sbar/NP = Sbar missing NP underneath (see our example)

As for slash rules…

- We need slash category introduction rule, e.g., Sbar $\rightarrow$ Comp S/NP
- We need 'elimination' rule NP/NP$\rightarrow$e
- These are paired (why?)
- We'll need other slash categories, e.g.,

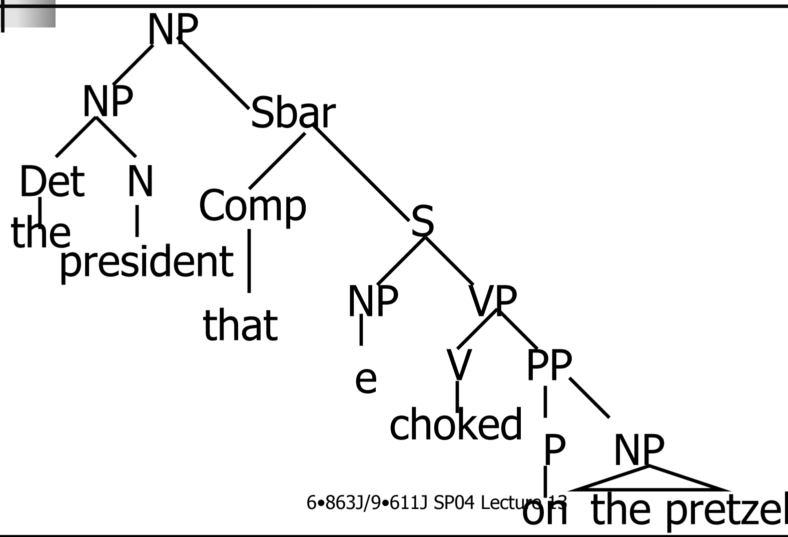
Need PP/NP…



How do we do 'slashed rules' systematically & formally

- Step 1: form *slashed categories*
  - *Basic categories:* 'orginary' nonterminals N={S, VP, NP, PP, …}
  - *Slashed (derived) categories:* α/β, α, β range over N
  - E.g., S/NP, S/VP, S/PP, NP/NP, NP/VP, NP/PP
  - Interpretation: tree rooted at α, with 'gap' (subtree) of type β somewhere beneath
- Step 2: form *slashed rules* from *basic rules*
  - *Basic rule:* S$\rightarrow$ NP VP
  - *Slashed rule:* S/NP$\rightarrow$ NP VP/NP
  - (Why not S/NP$\rightarrow$ NP/NP VP)

Also have ‘subject’ gaps



Filler-gap configuration

- Equivalent to notion of ‘scope’ for natural languages (scope of variables) ≈ Environment frame in Scheme/binding environment for ‘variables’ that are empty categories
- Formally: Fillers <u>c-command</u> gaps (constituent command)
- Definition of c-command:

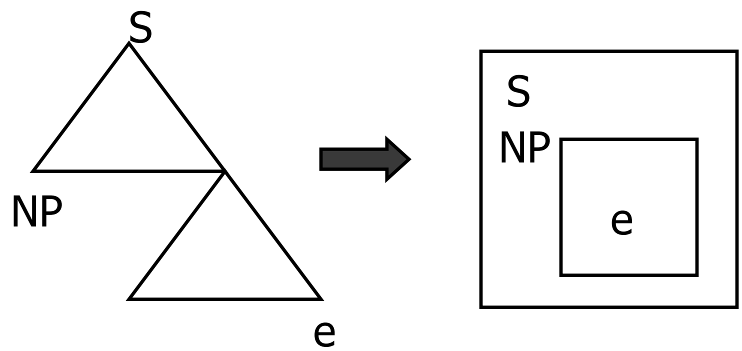
Constraints on filler-gap relations

- Can be "unbounded" on the surface, but underlyingly is *successive cyclic (AKA – forms a chain* linking filler to gap)
  - [what (F) did John think (F) that Bill said (F) that Mary liked (G)]
- Note that this F-G distance cannot exceed 1 adjacent S or NP boundary (in English)
  - What (F) [do you wonder [who likes (G)]
  - (Note: *What (F) do you wonder (F) who likes (G)* is blocked)

Constraints on filler-gaps

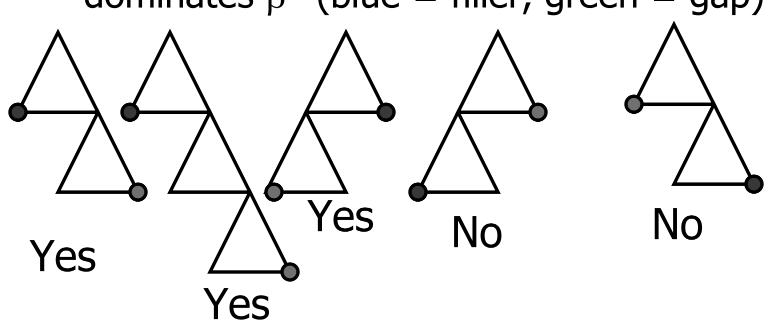
- Obeys structural relation called *c-command*
- True in other languages also; also true there are multiple gaps
- So, how does *generalized phrase structure grammar (GPSG)* handle all this?
- We covered: basic rules; *derived rules*
- Still to cover: *metarules; constraints*

Filler-gap configuration

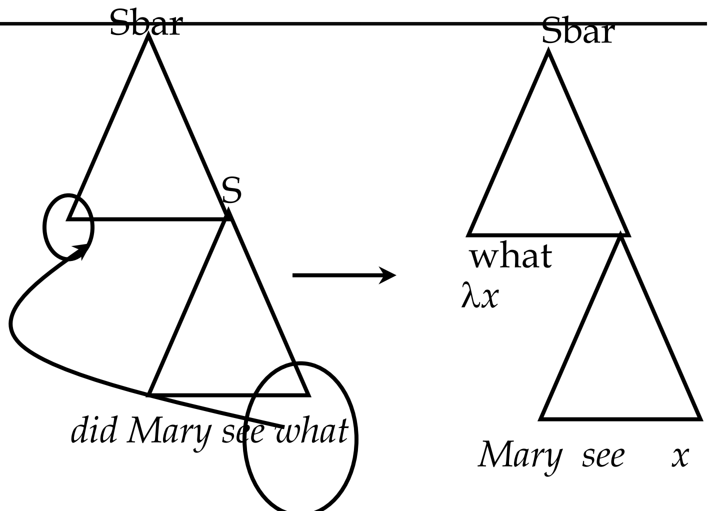


C-command

- A phrase α c-commands a phrase β iff the first branching node that dominates α also dominates β (blue = filler, green = gap)



Natural for λ abstraction



Constraints on gpsg rules

- "Across the board" constraints in conjunction

  The person who Mary likes (S/NP) and Sally hates George(S) computed my tax. Compare:

  The person who Mary likes (S/NP) and Sally hates (S/NP) computed my tax

  Can't join S/NP and S – different categories, akin to

  John likes pizza and beer (NP *and* NP)
- Extracted wh-phrase must be of same type

  Which book and which pencil did John buy?

  ? John asked who and where Bill had seen (G)

More constraints

- English specific
  **Who (F) do you believe (G) that came*
  **Who (F) did you wonder whether (G) came*
  **Who (F) did you wonder if (G) came*
  OK: *Who is it that Mary likes*
- What is going on here?

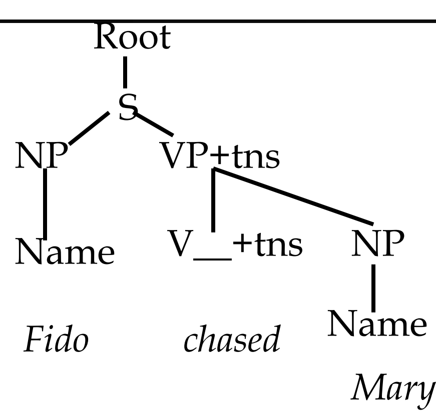
Rightward displacement

- *Harry caught, and Mary killed, the rabid dog*
- *The man (G) was ill who was here (F)*
- *John hummed (G) and Mary sang (G), at equal volumes (F)*
- Again can't be dissimilar
  John offered and Harry gave Bill a Volvo (*Bill a Volvo"* isn't a phrase)
- Again can't be "too far":
  Harry fished in the ocean and I don't think Mary in the sea.

Some examples to help with lab – corresponding tree structures (I won’t leave you at bay in a sea of nonterminals)

- If you start w/ tree structures, the CF rules write themselves (almost)
- *Fido chased Mary*

Structure for this sentence



Why do we need

- V2?
- V2+tns?

Verb subcategories

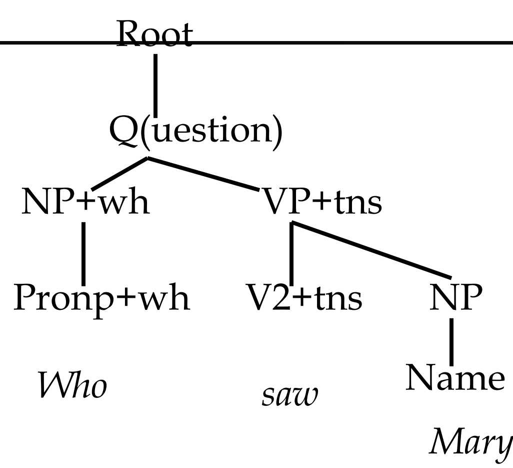
- You will need V1,V2, V3, V4,…

Now easy to read off rules from trees

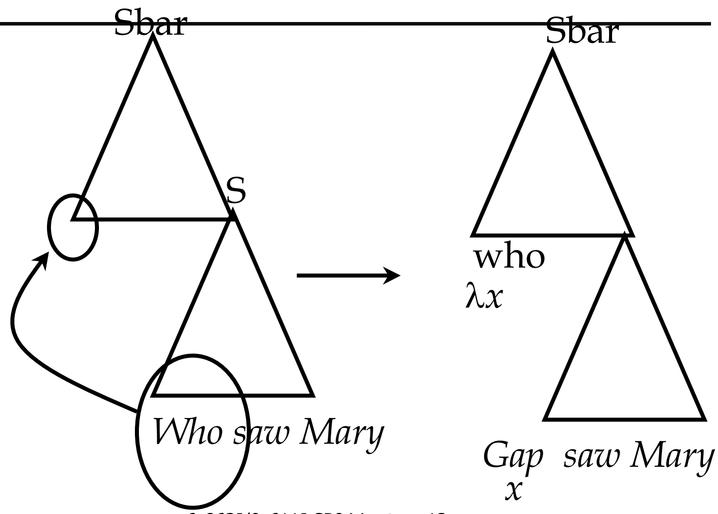
- $S \rightarrow NP\ VP+TNS$
- $VP+TNS \rightarrow V2+TNS\ NP$

Etc…

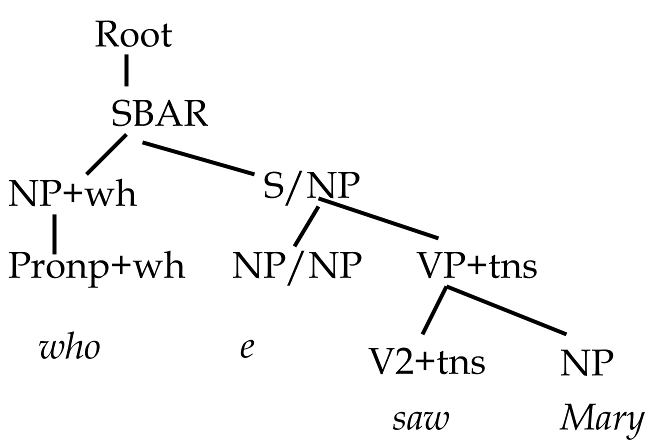
Idea 1: Wysiwyg



Idea 2: conform to wh-pattern of others, e.g., "What did John see"



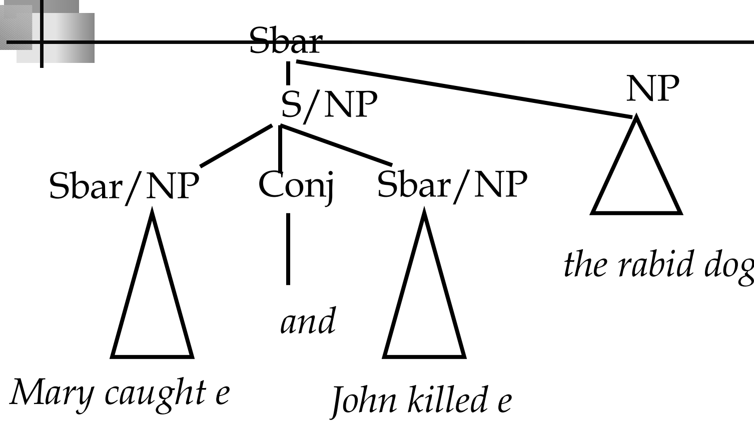
More complex syntax – simpler semantics (canonical)



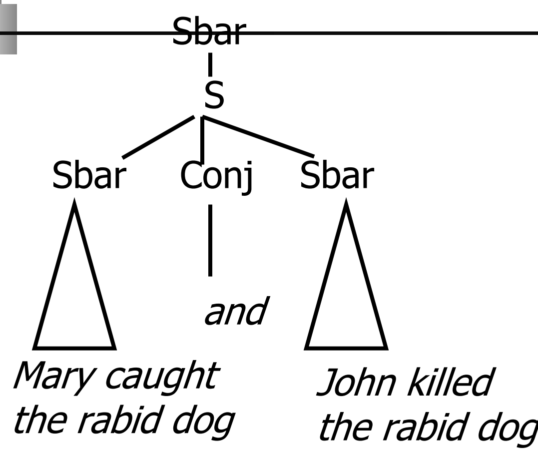
First alternative

- Syntactic structures ‘closer to the surface’
- Then we have to figure out semantic differences from hacking the semantic part
- In fact, this is what GPSG does for so-called `passive’ also – it doesn’t ‘encode’ this in a change from active sentence to passive sentence, e.g., *John ate the ice-cream* → *The ice-cream was eaten (by John)*
- Instead, it just has two forms. Is this right?
- Which form is ‘primary’? (more fundamental)
- Evidence: doesn’t seem to be cases where you have a passive form *without* the corresponding active form, but *does* seem to be cases the other way around (active but no passive)

Now, what if we move the object?



Another example



Besides reading off the rules…

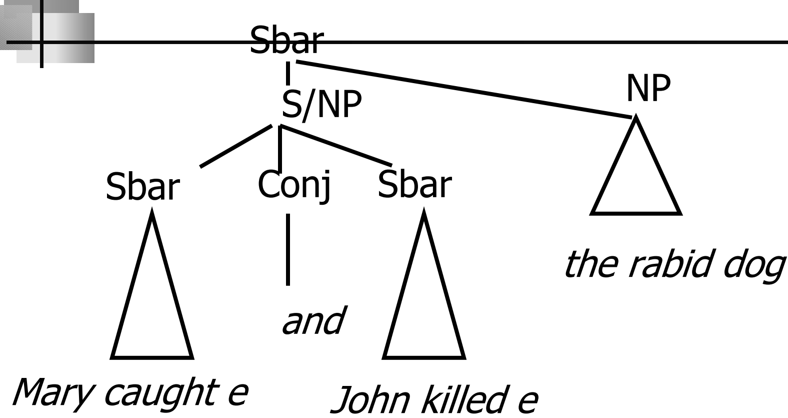
- Why can't we just build a machine to do this?
- We could induce rules from the structures
- But we have to know the right representations (structures) to begin with
- Penn treebank has structures – so could use learning program for that
- This is, as noted, a *construction based* approach
- We have to account for various *constraints*, as noted

Constraints – and language variation

- Examples:
  'Distance' effects: *What do you wonder who likes*
  (English): *must* have a subject (unlike Spanish) *I came; vs. came*
- How do we want to account for these?
- 2 possible ways

1. More engineering: make a list
2. More scientific: look for deeper theory that has primitives that only lets you `write the correct' rules – like automatic program construction

What if we move the object?



Why not read off the rules?

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So what?

- What about multiple fillers and gaps?
- Which violins are these sonatas difficult to play ______ on ______ ?

  (these sonatas, which violins)

How many context-free rules?

- For every displaced phrase, what do we do to the ‘regular’ context-free rules?
- How many kinds of displaced rules are there?

  Which book and Which pencil did Mary buy?

  *Mary asked who and what bought
- Well, how many???

And then..

- John saw more horses than bill saw cows or Mary talked to
- John saw more horses than bill saw cows or mary talked to cats
- The kennel which Mary made and Fido sleeps in has been stolen
- The kennel which Mary made and Fido sleeps has been stolen

How big can the grammar get???

- John sleeps
- They sleep
- I know her
- ?I know she
- Agreement features
- Quite systematic

Other languages; formalizing features

- Two kinds:

1. Syntactic features, purely grammatical function

   Example: Case in German (NOMinative, ACCusative, DATive case) – relative pronoun must agree w/ Case of verb with which it is construed

   Wer micht strak is, muss klug sein

   Who not strong is, must clever be

   NOM NOM

   Who isn't strong must be clever

Continuing this example

Ich nehme, wen du mir empfiehlst

I take whomever you me recommend

ACC ACC ACC

I take whomever you recommend to me

**Ich nehme, wen du vertraust*

I take whomever you trust

ACC ACC DAT

Other class of features

2. Syntactic features w/ meaning – example, number, def/indef., adjective degree

Hungarian

Akart egy könyvet

He-wanted a book

-DEF -DEF

egy könyv amit akart

A book which he-wanted

-DEF -DEF

The trouble with tribbles

morphology of a single word:

Verb[head=thrill, tense=present, num=sing, person=3,…] → thrills

projection of features up to a bigger phrase

VP[head=α, tense=β, num=γ…] → V[head=α, tense=β, num=γ…] NP
provided α is in the set TRANSITIVE-VERBS

agreement between sister phrases:

S[head=α, tense=β] → NP[num=γ,…] VP[head=α, tense=β, num=γ…]
provided α is in the set TRANSITIVE-VERBS

3 common ways to use features

morphology of a single word:

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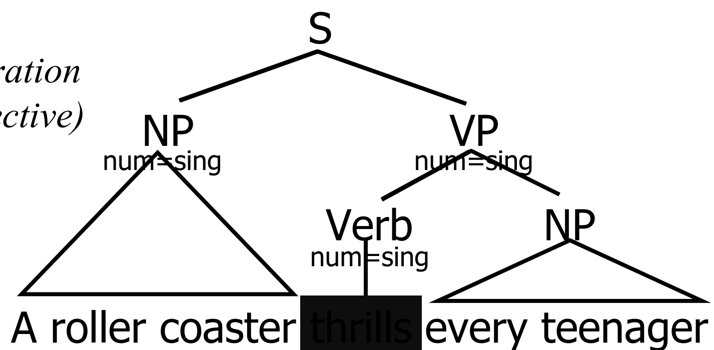
(generation perspective)



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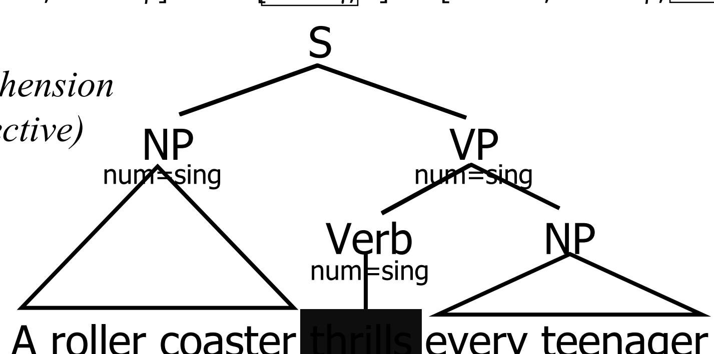
(comprehension perspective)

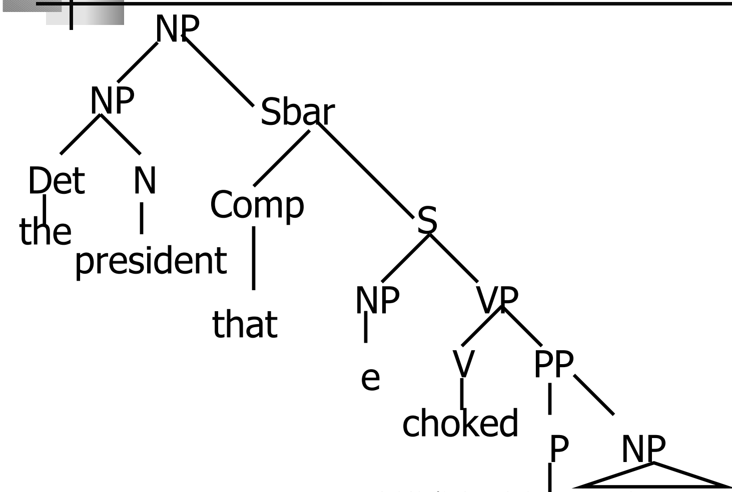


- But this means huge proliferation of rules…
- An alternative:
  - View terminals and non-terminals as complex objects with associated features, which take on different values
  - Write grammar rules whose application is constrained by tests on these features, e.g.
    - S → NP VP (only if the NP and VP agree in number)

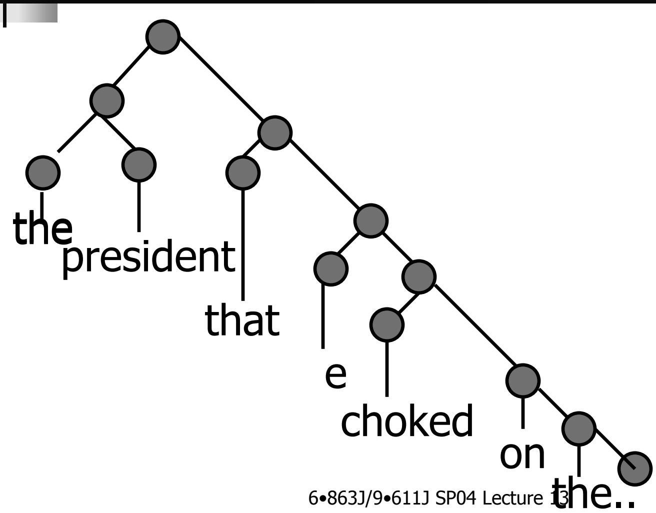
Design advantage

- Decouple skeleton syntactic structure from lexicon
- In fact, the syntactic structure really is a skeleton:

From this…



To this



Features are everywhere

morphology of a single word:

Verb[head=thrill, tense=present, num=sing, person=3,…] → thrills

projection of features up to a bigger phrase

VP[head=α, tense=β, num=γ…] → V[head=α, tense=β, num=γ…] NP

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agreement between sister phrases:

S[head=α, tense=β] → NP[num=γ,…] VP[head=α, tense=β, num=γ…]

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Better approach to factoring linguistic knowledge

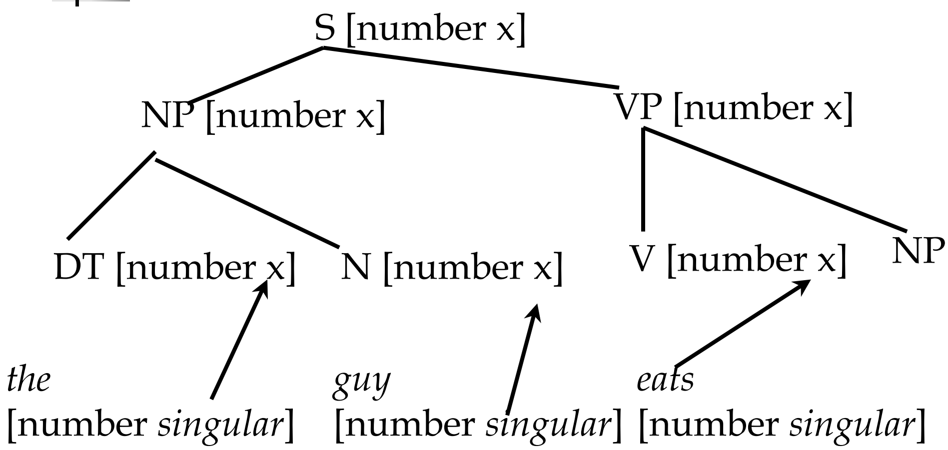
- Use the *superposition* idea: we superimpose one set of constraints on top of another:

1. Basic skeleton tree
2. Plus the added feature constraints

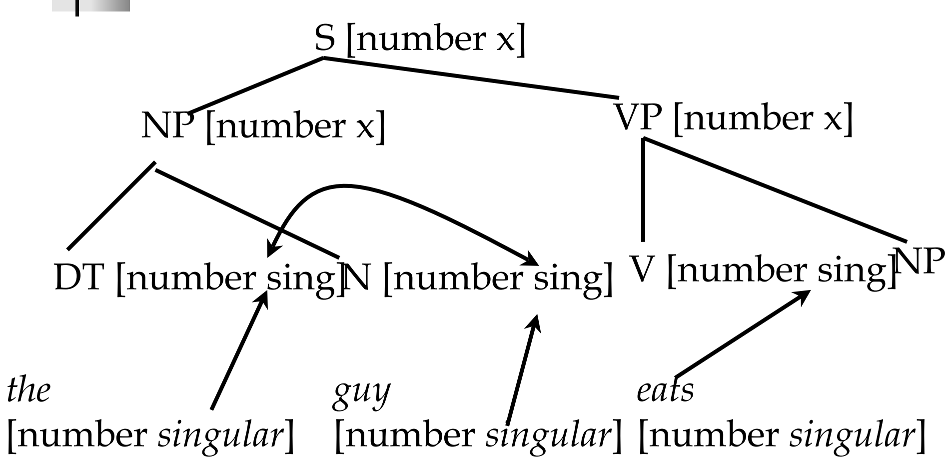
- S → NP VP

S	→	NP	VP
[num x]		[num x]	[num x]
		the guy	*eats*
		[num singular]	[num singular]

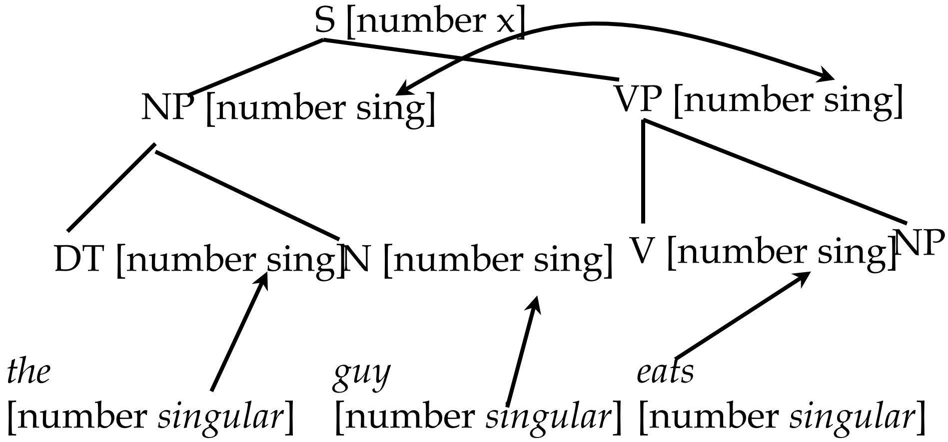
Or in tree form:



Values trickle up



Checking features



What sort of power do we need here?

- We have [*feature value*] combinations so far
- This seems fairly widespread in language
- We call these *atomic feature-value combinations*
- Other examples:

1. In English:

person feature (1^{st}, 2^{nd}, 3^{rd});

Case feature (degenerate in English: nominative, object/accusative, possessive/genitive): I know *her* vs. I know *she;*

Number feature: plural/sing; definite/indefinite

Degree: comparative/superlative

Feature Structures

- Sets of feature-value pairs where:
  - Features are atomic symbols
  - Values are atomic symbols or feature structures
  - Illustrated by attribute-value matrix

How to formalize?

- Let F be a finite set of feature names, let A be a set of feature values
- Let p be a function from feature names to permissible feature values, that is,

  $p: F \rightarrow 2^A$
- Now we can define a *word category* as a triple <*F, A, p*>
- This is a partial function from feature names to feature values

Example

- *F*= {CAT, PLU, PER}
- *p:*

  p(CAT)={V, N, ADJ}

  p(PER)={1, 2, 3}

  p(PLU)={+, -}

sleep = {[CAT V], [PLU -], [PER 1]}

sleep = {[CAT V], [PLU +], [PER 1]}

sleeps= {[CAT V], [PLU -], [PER 3]}

Checking whether features are compatible is relatively simple here…how bad can it get?

Operations on Feature Structures

- What will we need to do to these structures?
  - Check the compatibility of two structures
  - Merge the information in two structures
- We can do both using unification
- We say that two feature structures can be unified if the component features that make them up are compatible
  - [Num SG] U [Num SG] = [Num SG]
  - [Num SG] U [Num PL] fails!
  - [Num SG] U [Num []] = [Num SG]

- [Num SG] U [Pers 3] =
- Structures are compatible if they contain no features that are incompatible
- Unification of two feature structures:
  - Are the structures compatible?
  - If so, return the union of all feature/value pairs
- A failed unification attempt

Features, Unification and Grammars

- How do we incorporate feature structures into our grammars?
  - Assume that constituents are objects which have feature-structures associated with them
  - Associate sets of unification constraints with grammar rules
  - Constraints must be satisfied for rule to be satisfied
- For a grammar rule $\beta_0 \rightarrow \beta_1 \ldots \beta_n$
  - <β_i feature path> = Atomic value
  - <β_i feature path> = <β_j feature path>
- NB: if simple feat-val pairs, no arbitrary nesting, then no need for paths

Feature unification examples

(1) [agreement: [number: singular
person: first]]

(2) [agreement: [number: singular]
case: nominative]

- (1) and (2) *can* unify, producing (3):

(3) [agreement: [number: singular
person: first]
case: nominative]

(try overlapping the graph structures corresponding to these two)

Feature unification examples

1) [agreement: [number: singular
person: first]]

(2) [agreement: [number: singular]
case: nominative]

(4) [agreement: [number: singular
person: third]]

- (2) & (4) *can* unify, yielding (5):

(5) [agreement: [number: singular
person: third]
case: nominative]

- BUT (1) and (4) *cannot* unify because their values conflict on <agreement person>

- To enforce subject/verb number agreement

S → NP VP

<NP NUM> = <VP NUM>

Head Features

- Features of most grammatical categories are copied from <u>head</u> child to parent (e.g. from V to VP, Nom to NP, N to Nom, …)
- These normally written as 'head' features, e.g.

VP → V NP

<VP HEAD> = <V HEAD>

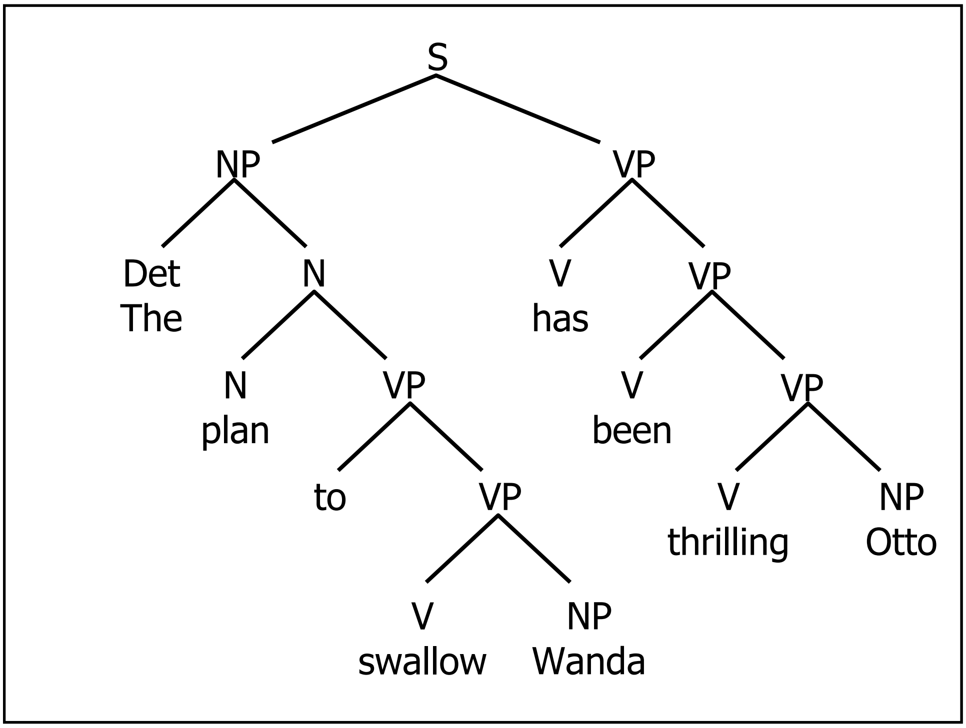
NP → Det Nom

<NP→ HEAD> = <Nom HEAD>

<Det HEAD AGR> = <Nom HEAD AGR>

Nom → N

<Nom HEAD> = <N HEAD>


S
NP
VP
Det
The
N
V
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V
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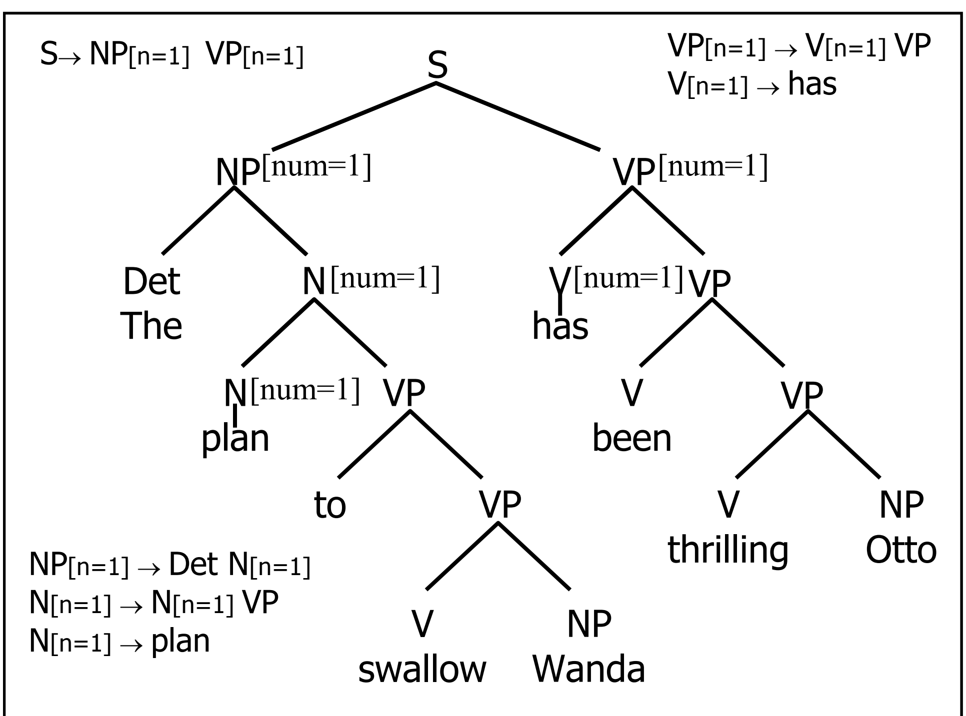
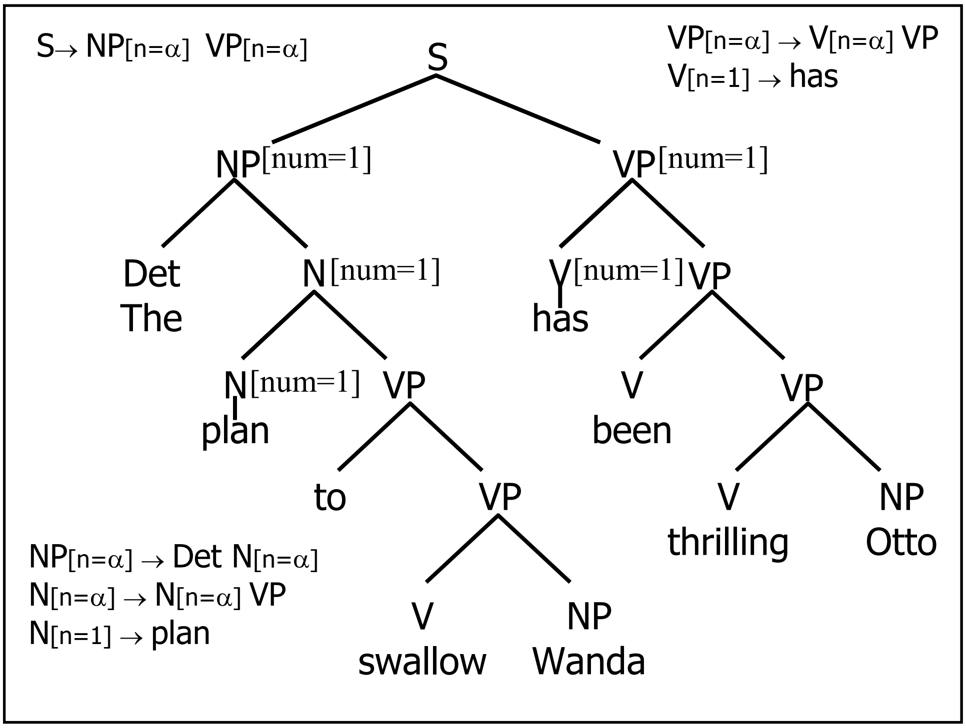
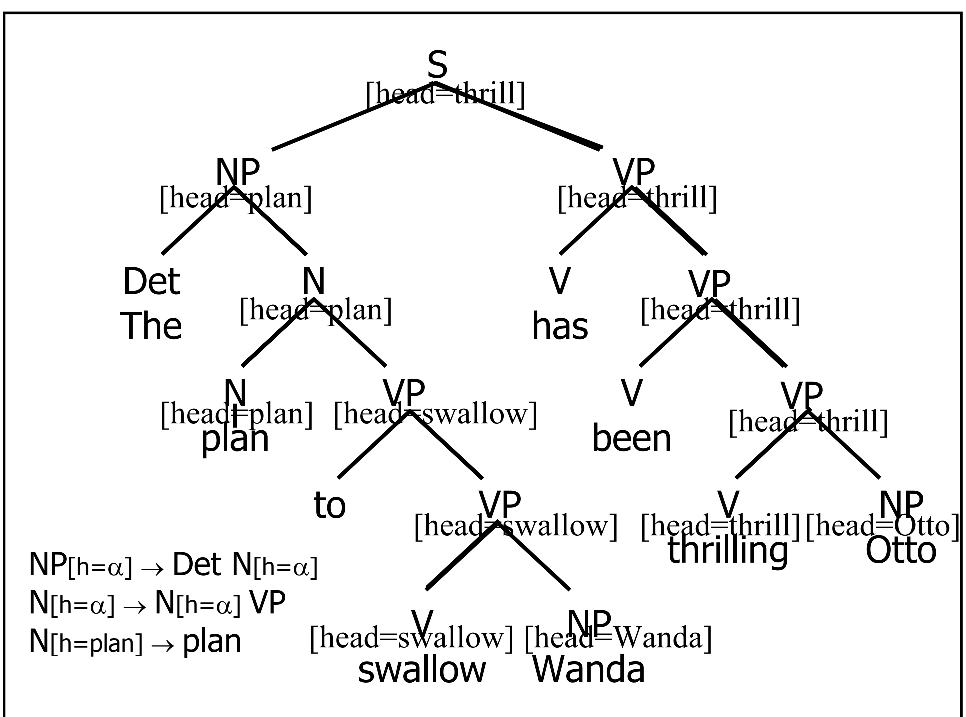
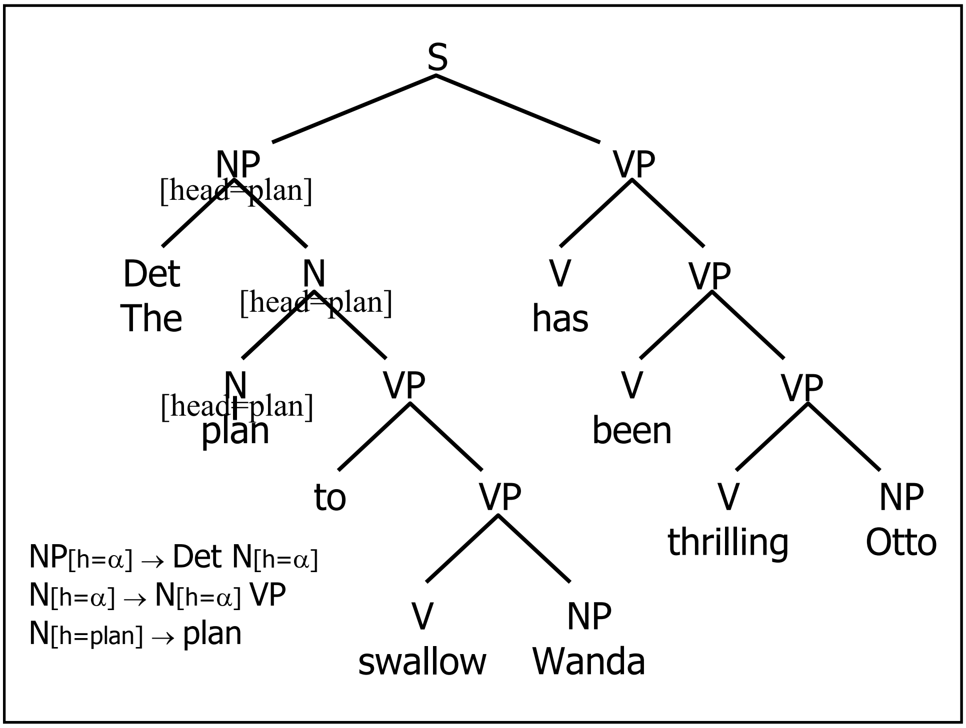
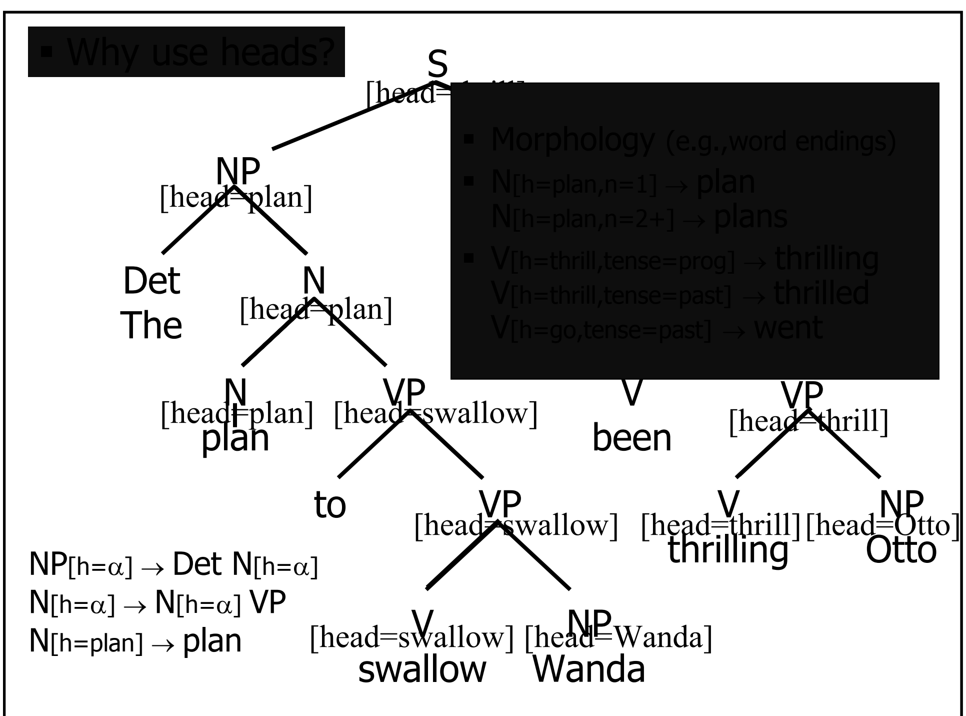
VP
to
VP
V
thrilling
NP
Otto
V
swallow
NP
Wanda


S→ NP[n=1] VP[n=1]
VP[n=1] → V[n=1] VP
V[n=1] → has
S
NP[num=1]
VP[num=1]
Det
The
N[num=1]
V[num=1]
has
VP
N[num=1]
plan
VP
V
been
VP
to
VP
V
thrilling
NP
Otto
NP[n=1] → Det N[n=1]
N[n=1] → N[n=1] VP
N[n=1] → plan
V
swallow
NP
Wanda

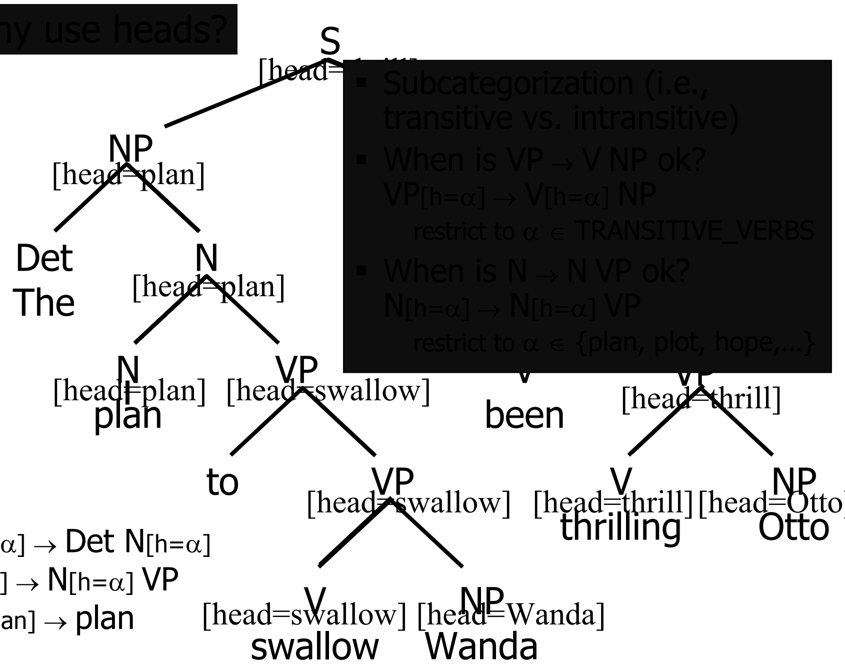

S→ NP[n=α] VP[n=α]
VP[n=α] → V[n=α] VP
V[n=1] → has
S
NP[num=1]
VP[num=1]
Det
The
N [num=1]
V [num=1]
has
VP
N [num=1]
plan
VP
V
been
VP
to
VP
V
thrilling
NP
Otto
NP[n=α] → Det N[n=α]
N[n=α] → N[n=α] VP
N[n=1] → plan
V
swallow
NP
Wanda


S
[head=thrill]
NP
[head=plan]
VP
[head=thrill]
Det
The
N
[head=plan]
V
has
VP
[head=thrill]
N
[head=plan]
plan
VP
[head=swallow]
V
been
VP
[head=thrill]
to
VP
[head=swallow]
V
[head=thrill]
thrilling
NP
[head=Otto]
Otto
NP[h=α] → Det N[h=α]
N[h=α] → N[h=α] VP
N[h=plan] → plan
V
[head=swallow]
swallow
NP
[head=Wanda]
Wanda


S
NP
[head=plan]
VP
Det
The
N
[head=plan]
V
has
VP
N
[head=plan]
plan
VP
V
been
VP
to
VP
V
thrilling
NP
Otto
V
swallow
NP
Wanda
NP[h=α] → Det N[h=α]
N[h=α] → N[h=α] VP
N[h=plan] → plan


[redacted]
S
NP
[head=plan]
Det
The
N
[head=plan]
[redacted]
N
[head=plan]
plan
VP
[head=swallow]
V
been
VP
[head=thrill]
to
VP
[head=swallow]
V
[head=thrill]
thrilling
NP
[head=Otto]
Otto
V
[head=swallow]
swallow
NP
[head=Wanda]
Wanda
NP[h=α] → Det N[h=α]
N[h=α] → N[h=α] VP
N[h=plan] → plan

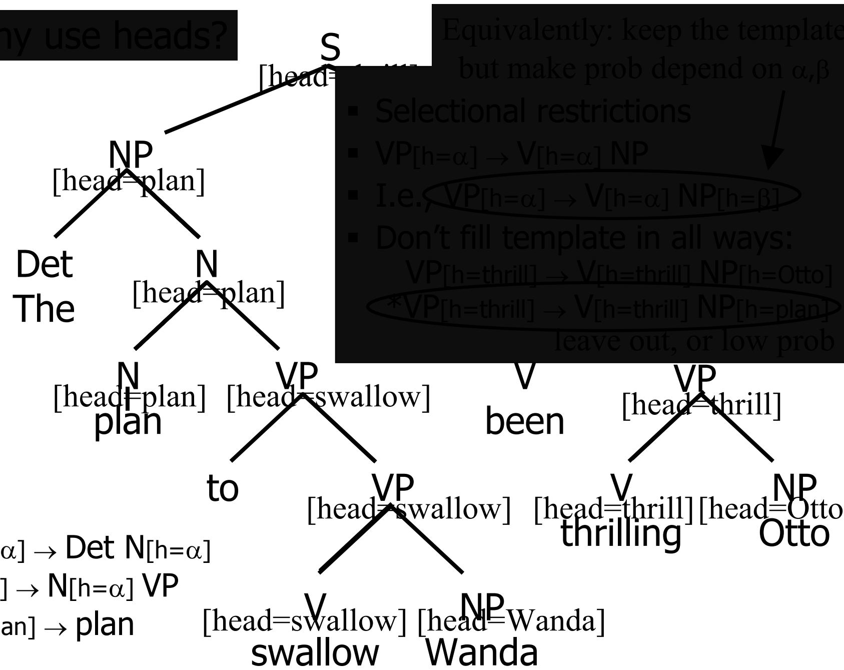
[redacted]



[redacted]

NP[h=α] → Det N[h=α]
N[h=α] → N[h=α] VP
N[h=plan] → plan

[redacted]



[redacted]

NP[h=α] → Det N[h=α]
N[h=α] → N[h=α] VP
N[h=plan] → plan

- How do we define 3plNP?
- How does this improve over the CFG solution?

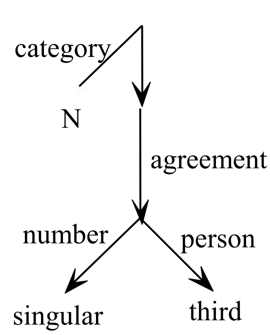
Feature values can be feature structures themselves

- Useful when certain features commonly co-occur, e.g. number and person
- Feature path: path through structures to value (e.g.

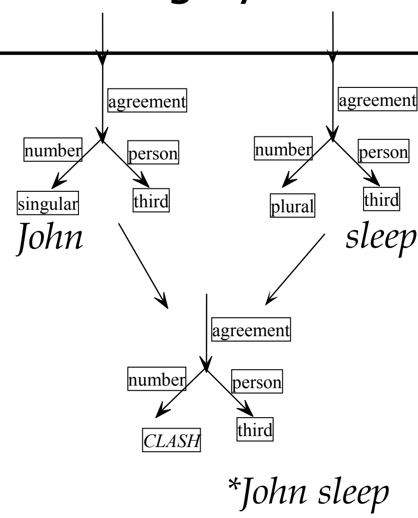
  Agr → Num → SG

Features and grammars

[category: N
  agreement: [person: third
               number: singular]]



Feature checking by unification



Our feature structures

- **`NP[agr ?B] -> DET[agr ?B] N[agr ?B]`**
- **`VP[fin ?A, agr ?B] -> V2[fin ?A, agr ?B] NP`**
- **`Maria NAME[agr [person 3, plural -]]`**

Kimmo entry for Verb (eg, 'coge' after analysis):

- **`+e Suffix    "[fin +, agr [tense pres,`**
  `mode ind, person 3, plural -]]"`

How can we parse with feature structures?

- Unification operator: takes 2 features structures and returns *either* a merged feature structure or *fail*
- Input structures represented as DAGs
  - Features are labels on edges
  - Values are atomic symbols or DAGs
- Unification algorithm goes through features in one input DAG_1 trying to find corresponding features in DAG_2 – if all match, success, else fail
- WE WILL USE MUCH SIMPLER kind of feature structure

Features and Earley Parsing

- Goal:
  - Use feature structures to provide richer representation
  - Block entry into chart of ill-formed constituents
- Changes needed to Earley
  - Add feature structures to grammar rules, & lexical entries
  - Add field to states containing set representing feature structure corresponding to state of parse, e.g.

    S → • NP VP, [0,0], [], Set= [Agr [plural -]]

- Add new test to Completer operation
  - Recall: Completer adds new states to chart by finding states whose • can be advanced (i.e., category of next constituent matches that of completed constituent)
  - Now: Completer will only advance those states if their feature structures unify
- New test for whether to enter a state in the chart
  - Now feature structures may differ, so check must be more complex
  - Suppose feature structure is more specific than existing one tied to this state? Do we add it?

Evidence that you don't need this much power

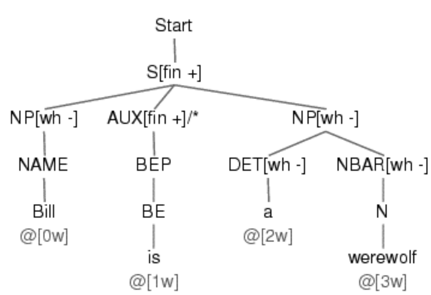
- Linguistic evidence: looks like you just check whether features are *nondistinct*, rather than equal or not – variable *matching,* not variable substitution
- Full unification lets you generate unnatural languages: a^i, *s.t. i a power of 2* – e.g., *a, aa, aaaa, aaaaaaaa, …* why is this 'unnatural' – another (seeming) property of natural languages:

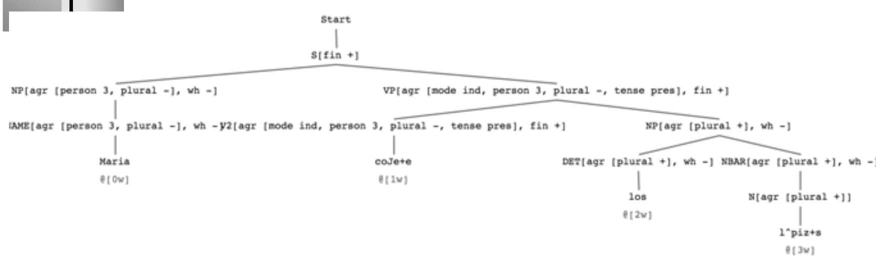
Natural languages seem to obey a *constant growth* property

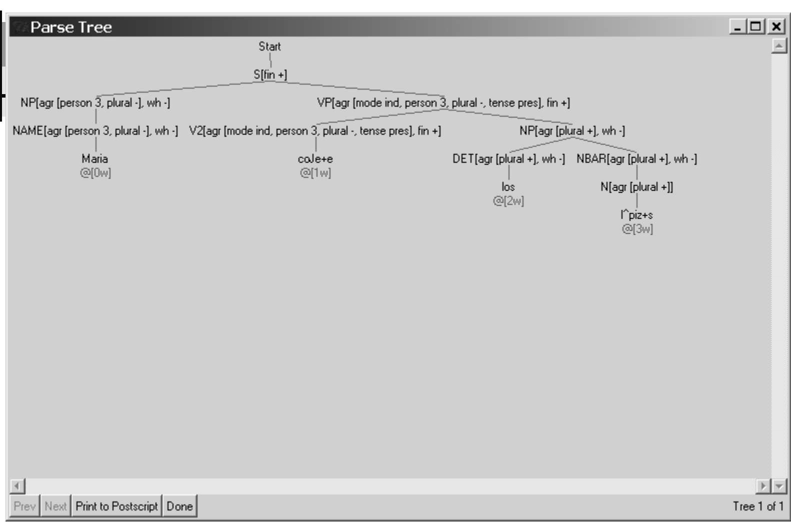
Parsing with features – hook from kimmo to earley

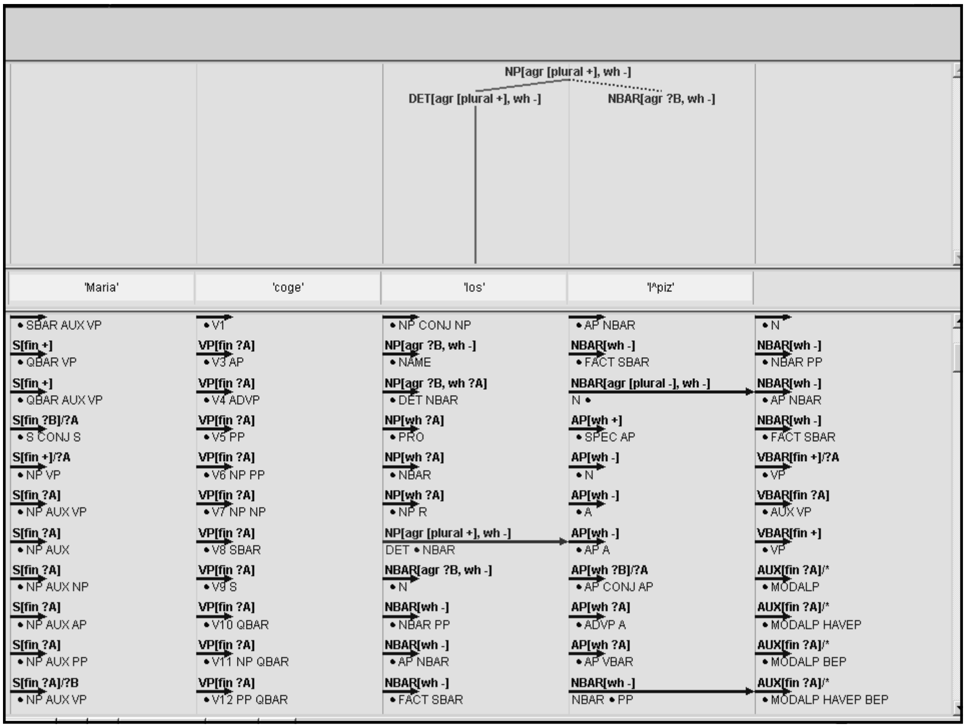
- Features written in this form (in Kimmo)
- **+as Suffix "[fin +, agr [tense pres, mode ind, person 2, plural -]]"**
- In general:
  [feature value, feature [feature val, …, feature val]]

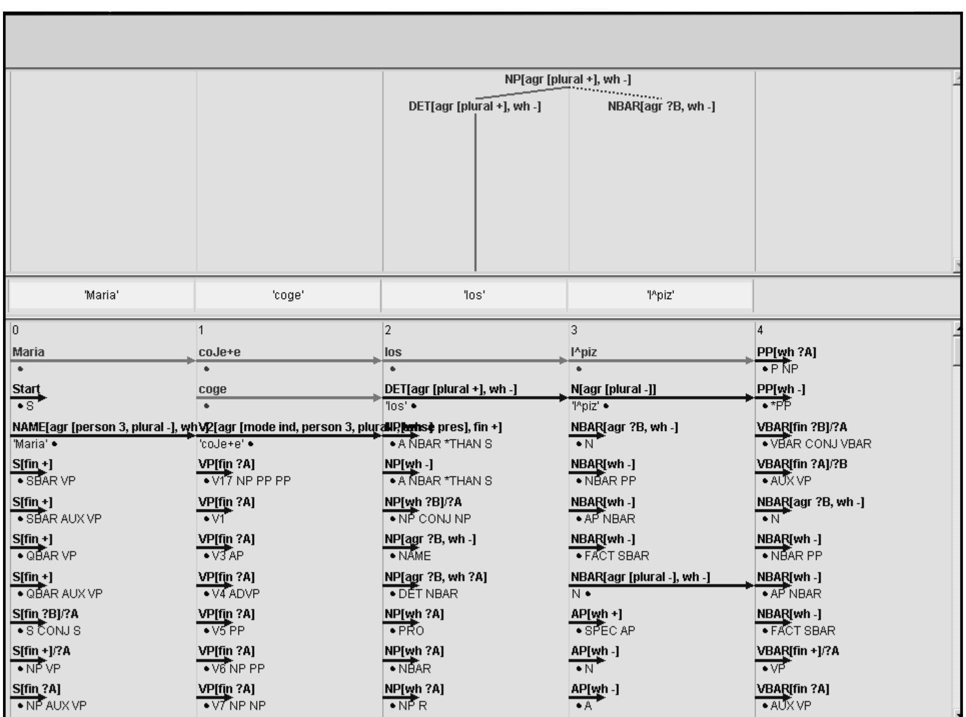
Where wolf

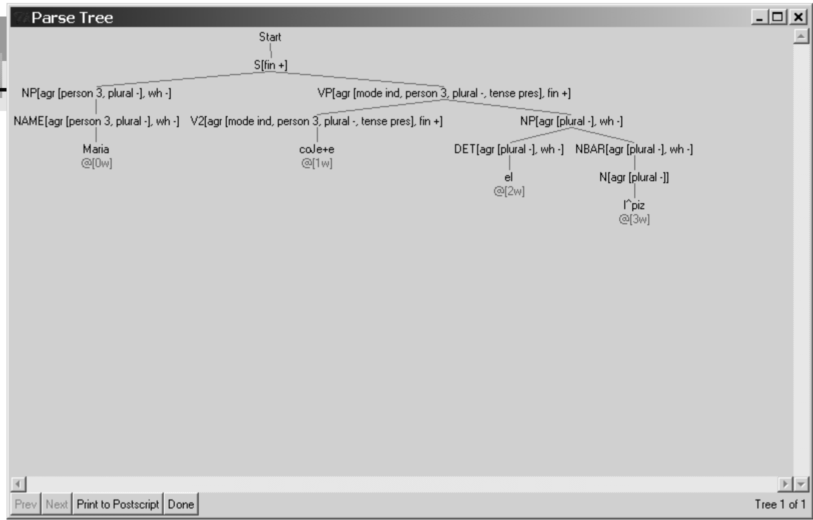



Start
S[fin +]
NP[agr [person 3, plural -], wh -]
VP[agr [mode ind, person 3, plural -, tense pres], fin +]
NAME[agr [person 3, plural -], wh -]
V2[agr [mode ind, person 3, plural -, tense pres], fin +]
NP[agr [plural +], wh -]
Maria
@[0w]
coJe+e
@[1w]
DET[agr [plural +], wh -]
NBAR[agr [plural +], wh -]
los
@[2w]
N[agr [plural +]]
l^piz+s
@[3w]


Parse Tree
Start
S[fin +]
NP[agr [person 3, plural -], wh -]
VP[agr [mode ind, person 3, plural -, tense pres], fin +]
NAME[agr [person 3, plural -], wh -]
V2[agr [mode ind, person 3, plural -, tense pres], fin +]
NP[agr [plural +], wh -]
Maria
@[0w]
coJe+e
@[1w]
DET[agr [plural +], wh -]
NBAR[agr [plural +], wh -]
los
@[2w]
N[agr [plural +]]
l^piz+s
@[3w]
Prev
Next
Print to Postscript
Done
Tree 1 of 1


NP[agr [plural +], wh -]
DET[agr [plural +], wh -]
NBAR[agr ?B, wh -]
'Maria'
'coge'
'los'
'l^piz'
• SBAR AUX VP
S[fin +]
• QBAR VP
S[fin +]
• QBAR AUX VP
S[fin ?B]/?A
• S CONJ S
S[fin +]/?A
• NP VP
S[fin ?A]
• NP AUX VP
S[fin ?A]
• NP AUX
S[fin ?A]
• NP AUX NP
S[fin ?A]
• NP AUX AP
S[fin ?A]
• NP AUX PP
S[fin ?A]/?B
• NP AUX VP
• V1
VP[fin ?A]
• V3 AP
VP[fin ?A]
• V4 ADVP
VP[fin ?A]
• V5 PP
VP[fin ?A]
• V6 NP PP
VP[fin ?A]
• V7 NP NP
VP[fin ?A]
• V8 SBAR
VP[fin ?A]
• V9 S
VP[fin ?A]
• V10 QBAR
VP[fin ?A]
• V11 NP QBAR
VP[fin ?A]
• V12 PP QBAR
• NP CONJ NP
NP[agr ?B, wh -]
• NAME
NP[agr ?B, wh ?A]
• DET NBAR
NP[wh ?A]
• PRO
NP[wh ?A]
• NBAR
NP[wh ?A]
• NP R
NP[agr [plural +], wh -]
DET • NBAR
NBAR[agr ?B, wh -]
• N
NBAR[wh -]
• NBAR PP
NBAR[wh -]
• AP NBAR
NBAR[wh -]
• FACT SBAR
• AP NBAR
NBAR[wh -]
• FACT SBAR
NBAR[agr [plural -], wh -]
N •
AP[wh +]
• SPEC AP
AP[wh -]
• N
AP[wh -]
• A
AP[wh -]
• AP A
AP[wh ?B]/?A
• AP CONJ AP
AP[wh ?A]
• ADVP A
AP[wh ?A]
• AP VBAR
NBAR[wh -]
NBAR • PP
• N
NBAR[wh -]
• NBAR PP
NBAR[wh -]
• AP NBAR
NBAR[wh -]
• FACT SBAR
VBAR[fin +]/?A
• VP
VBAR[fin ?A]
• AUX VP
VBAR[fin +]
• VP
AUX[fin ?A]/*
• MODALP
AUX[fin ?A]/*
• MODALP HAVEP
AUX[fin ?A]/*
• MODALP BEP
AUX[fin ?A]/*
• MODALP HAVEP BEP


NP[agr [plural +], wh -]
DET[agr [plural +], wh -]
NBAR[agr ?B, wh -]
'Maria'
'coge'
'los'
'l^piz'
0
Maria
•
Start
• S
NAME[agr [person 3, plural -], wh
'Maria' •
S[fin +]
• SBAR VP
S[fin +]
• SBAR AUX VP
S[fin +]
• QBAR VP
S[fin +]
• QBAR AUX VP
S[fin ?B]/?A
• S CONJ S
S[fin +]/?A
• NP VP
S[fin ?A]
• NP AUX VP
1
coJe+e
•
coge
•
V2[agr [mode ind, person 3, plural -], tense pres], fin +]
'coJe+e' •
VP[fin ?A]
• V17 NP PP PP
VP[fin ?A]
• V1
VP[fin ?A]
• V3 AP
VP[fin ?A]
• V4 ADVP
VP[fin ?A]
• V5 PP
VP[fin ?A]
• V6 NP PP
VP[fin ?A]
• V7 NP NP
2
los
•
DET[agr [plural +], wh -]
'los' •
• A NBAR *THAN S
NP[wh -]
• A NBAR *THAN S
NP[wh ?B]/?A
• NP CONJ NP
NP[agr ?B, wh -]
• NAME
NP[agr ?B, wh ?A]
• DET NBAR
NP[wh ?A]
• PRO
NP[wh ?A]
• NBAR
NP[wh ?A]
• NP R
3
l^piz
•
N[agr [plural -]]
'l^piz' •
NBAR[agr ?B, wh -]
• N
NBAR[wh -]
• NBAR PP
NBAR[wh -]
• AP NBAR
NBAR[wh -]
• FACT SBAR
NBAR[agr [plural -], wh -]
N •
AP[wh +]
• SPEC AP
AP[wh -]
• N
AP[wh -]
• A
4
PP[wh ?A]
• P NP
PP[wh -]
• *PP
VBAR[fin ?B]/?A
• VBAR CONJ VBAR
VBAR[fin ?A]/?B
• AUX VP
NBAR[agr ?B, wh -]
• N
NBAR[wh -]
• NBAR PP
NBAR[wh -]
• AP NBAR
NBAR[wh -]
• FACT SBAR
VBAR[fin +]/?A
• VP
VBAR[fin ?A]
• AUX VP



Constant growth property

Claim: ∃ Bound <u>k</u> on the ‘distance gap’ between any two consecutive sentences in this list, which can be specified in advance (fixed)

- ‘Intervals’ between valid sentences cannot get too big – cannot grow w/o bounds
- We can do this a bit more formally

Constant growth

- Dfn. A language L is *semilinear* if the number of occurrences of each symbol in any string of L is a linear combination of the occurrences of these symbols in some fixed, finite set of strings of L.
- Dfn. A language L is *constant growth* if there is a constant c_0 and a finite set of constants C s.t. for all $w \in L$, where $|w| > c_0 \exists w' \in L$ s.t. $|w| = |w'| + c$, some $c \in C$
- Fact. (Parikh, 1971). Context-free languages are semilinear, and constant-growth
- Fact. (Berwick, 1983). The power of 2 language is non constant-growth

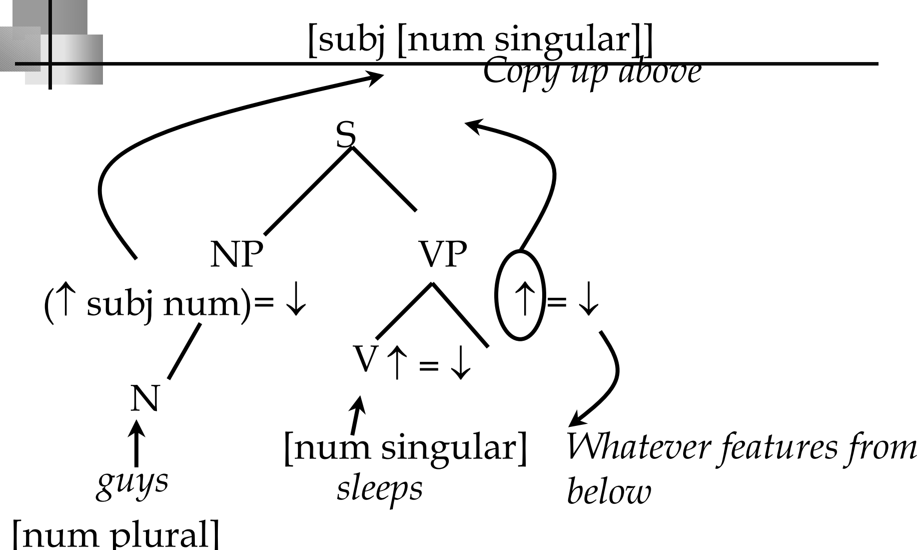
General feature grammars – how violate these properties

- Take example from so-called "lexical-functional grammar" but this applies as well to any general unification grammar
- Lexical functional grammar (LFG): add checking rules to CF rules (also variant HPSG)

Example LFG

- Basic CF rule:
  S→NP VP
- Add corresponding ‘feature checking’
  S→ NP VP
  (↑ subj num)= ↓ ↑ = ↓
- What is the interpretation of this?

Applying feature checking in LFG



Alas, this allows non-constant growth, unnatural languages

- Can use LFG to generate power of 2 language
- Very simple to do
- $A \rightarrow A \quad A$

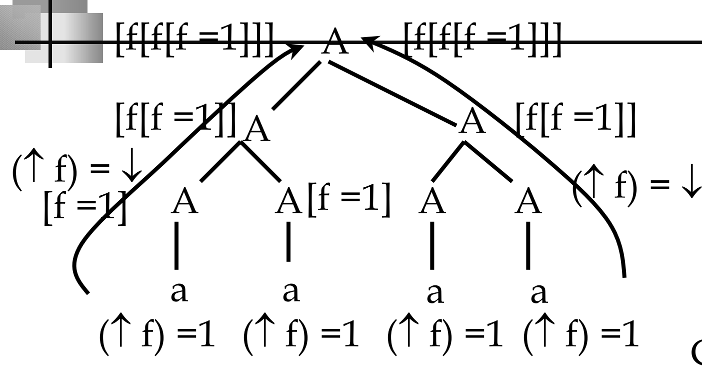
  $(\uparrow f) = \downarrow \quad (\uparrow f) = \downarrow$

  $A \rightarrow a$

  $(\uparrow f) = 1$

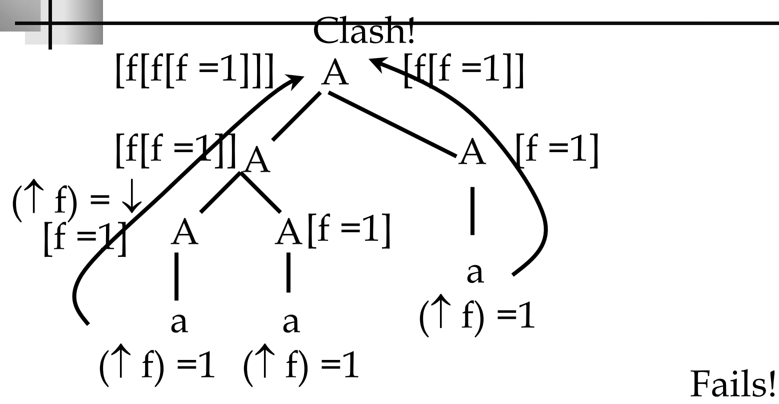
Lets us `count' the number of embeddings on the right & the left – make sure a power of 2

Example



Checks ok

If mismatch anywhere, get a feature clash…



Conclusion then

- If we use too powerful a formalism, it lets us write 'unnatural' grammars
- This puts burden on the person writing the grammar – which may be ok.
- However, child doesn't presumably do this (they don't get 'late days')
- We want to strive for automatic programming – ambitious goal