An Introduction to Head-Driven Phrase Structure Grammar

Stefan Müller

Friedrich Schiller University Jena

e-mail: `Stefan.Mueller@dfki.de`

`http://www.dfki.de/˜stefan/`

Aims of the Course

- introduction to the basic ideas of Head-Driven Phrase Structure Grammar
- motivation of the feature geometry that is used in current publications enable you to read HPSG specific publications

General Things

- Prerequisits: Some knowledge of phrase structure grammar.
- Who are you?
- Ask Questions!

Outline

Why Syntax?

- Signs: form meaning pairs (Saussure, 1915)
- Language $\stackrel{?}{=}$ list of strings
- language is finite if we assume an upper bound for sentence length

(1) This sentence goes on and on and on ...

infinitely many sentences, brain capacity is finite → we need structure/patterns

- words, phrases, sentences
- meaning of an utterance from meaning of its parts

(2) The woman knows the man.

- syntax: the way the combination takes place, structure

Why Formal?

Precisely constructed models for linguistic structure can play an important role, both negative and positive, in the process of discovery itself. By pushing a precise but inadequate formulation to an unacceptable conclusion, we can often expose the exact source of this inadequacy and, consequently, gain a deeper understanding of the linguistic data. More positively, a formalized theory may automatically provide solutions for many problems other than those for which it was explicitly designed. Obscure and intuition-bound notions can neither lead to absurd conclusions nor provide new and correct ones, and hence they fail to be useful in two important respects. I think that some of those linguists who have questioned the value of precise and technical development of linguistic theory have failed to recognize the productive potential in the method of rigorously stating a proposed theory and applying it strictly to linguistic material with no attempt to avoid unacceptable conclusions by ad hoc adjustments or loose formulation. (Chomsky, 1957, p. 5)

As is frequently pointed out but cannot be overemphasized, an important goal of formalization in linguistics is to enable subsequent researchers to see the defects of an analysis as clearly as its merits; only then can progress be made effi ciently. (Dowty, 1979, p. 322)

- What does an analysis mean?
- What does it predict?
- Why are alternative analyses excluded?
- Only formal grammars can be used with computers.

Phrases/Constituents (I)

- *Substitutability*: If we can exchange a sequence of words against another sequence of words and the result is still grammatical, both sequences are likely to be constituents.

(3) a. He knows the man.
 b. He knows a woman.

- *Permutability*: Sequences that can be permuted without making a sentence ungrammatical are constituents:

(4) a. weil keiner diese Frau kennt.
 because nobody$_{nom}$ this woman$_{acc}$ knows
 'because nobody knows this woman.'
 b. weil diese Frau keiner kennt.
 because this woman$_{acc}$ nobody$_{nom}$ knows

Phrases/Constituents (II)

- *Pronominalizability*: Everything that we can refer to with a pronoun is a constituent.

(5) a. The man sleeps.
 b. He sleeps.

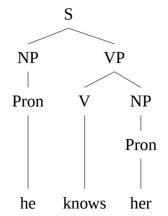
- *Coordination test*: Things that can be coordinated are constituents:

(6) The man and the woman work.

- *Question test*: What we can ask for is a constituent.

(7) a. The man works.
 b. Who does work?

A Simple Phrase Structure Grammar for English



S $\rightarrow$ NP, VP
VP $\rightarrow$ V, NP
NP $\rightarrow$ Pron
Pron $\rightarrow$ *he*
Pron $\rightarrow$ *him*
Pron $\rightarrow$ *her*
V $\rightarrow$ *knows*

(8) a. He knows her.
b. * We knows her.

What is wrong?
Person and number of *we* and verb

Person Number Agreement

(9) a. I/you/we/you/they sleep.
b. He sleeps.

(10) I am / you are / he is / we/you/they are . . .

To capture the fact that subject and verb agree in person and number we have to use more complex symbols:

S $\rightarrow$ NP_1_sg, VP_1_sg	NP_1_sg $\rightarrow$ Pron_1_sg
S $\rightarrow$ NP_2_sg, VP_2_sg	NP_2_sg $\rightarrow$ Pron_2_sg
S $\rightarrow$ NP_3_sg, VP_3_sg	NP_3_sg $\rightarrow$ Pron_3_sg
. . .	. . .
VP_1_sg $\rightarrow$ V_1_sg, NP	Pron_3_sg $\rightarrow$ *he*
VP_2_sg $\rightarrow$ V_2_sg, NP	Pron_3_sg $\rightarrow$ *him*
VP_3_sg $\rightarrow$ V_3_sg, NP	Pron_3_sg $\rightarrow$ *her*
. . .	V_3_sg $\rightarrow$ *knows*

Problems with this Approach

- the number of non-terminal symbols explodes
- in rules like
  VP_1_sg $\rightarrow$ V_1_sg, NP
  VP_2_sg $\rightarrow$ V_2_sg, NP
  VP_3_sg $\rightarrow$ V_3_sg, NP
  what does NP stand for?
  Instead we had to write NP_1_sg or NP_2_sg or . . . in each rule
  $\rightarrow$ explosion of the number of rules
- missing generalization
- Solution: Features

Person Number Agreement: Rules with Features

(11) a. I/you/we/you/they sleep.
b. He sleeps.

(12) I am / you are / he is / we/you/they are . . .

S $\rightarrow$ NP(Per,Num), VP(Per,Num)
VP(Per,Num) $\rightarrow$ V(Per,Num), NP(Per2,Num2)
NP(Per,Num) $\rightarrow$ Pron(Per,Num)
Pron(3,sg) $\rightarrow$ *he*
V(3,sg) $\rightarrow$ *knows*

things in the brackets written in capital letters are variables

the value of Per and Num in the rules does not matter

important: Per and Num of NP and VP are equal

Per2, Num2 do not matter since they do not appear anywhere else

Feature Bundles

- are there rules where Per values have to be identical, but Num values may be not?

  S $\to$ NP(Per,Num), VP(Per,Num)
  VP(Per,Num) $\to$ V(Per,Num), NP(Per2,Num2)
  NP(Per,Num) $\to$ Pron(Per,Num)
  Pron(3,sg) $\to$ *he*
  V(3,sg) $\to$ *knows*

- structuring of information: Per and Num are grouped together and referred to with Arg:

  S $\to$ NP(Agr), VP(Agr)
  VP(Agr) $\to$ V(Agr), NP(Agr2)
  NP(Agr) $\to$ Pron(Agr)
  Pron(agr(3,sg)) $\to$ *he*
  V(agr(3,sg)) $\to$ *knows*

- value of Agr is a complex structure that contains information about person and number
- important in HPSG: information is shared by mothers and daughters or between daughters in a rule

Heads

A head determines the most important features of a phrase/projection.

(13) a. Karl **sleeps**.
b. Karl **talks** about linguistics.
c. **about** linguistics
d. a **man**

A (fi nite) sentence is a maximal projection of a (fi nite) verb.

main categories are:

category	projected features
verb	part of speech, verb form (*fin*, *bse*, . . .)
noun	part of speech, case
preposition	part of speech, form of the preposition
adjective	part of speech

Abstraction over Rules

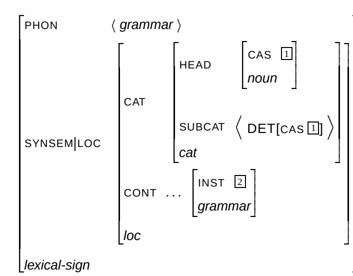
$\overline{X}$ -Theory (Jackendoff, 1977):

$\overline{X}$ – Rule	examples with instantiated part of speech
$\overline{\overline{X}} \to \overline{\overline{\text{Specifi er}}}\ \overline{X}$	$\overline{\overline{N}} \to \overline{\overline{\text{DET}}}\ \overline{N}$
$\overline{X} \to \overline{X}\ \overline{\overline{\text{Adjunct}}}$	$\overline{N} \to \overline{N}\ \overline{\overline{\text{REL\_CLAUSE}}}$
$\overline{X} \to \overline{\overline{\text{Adjunct}}}\ \overline{X}$	$\overline{N} \to \overline{\overline{\text{ADJ}}}\ \overline{N}$
$\overline{X} \to X\ \overline{\overline{\text{Complement}}}*$	$\overline{N} \to \text{N}\ \overline{\overline{\text{P}}}$

X stands for an arbitrary category (the head), ‘*’ for arbitrarily many repetitions

Overall Approach

- Surface-Based
- Monostratal Theory
- Lexicalized (Head-Driven)
- Sign-Based (Saussure, 1915)
- Typed Feature Structures (Lexical Entries, Morphology, Phrases, Principles)
- Multiple Inheritance
  - Phonology
  - Syntax
  - Semantics



Feature Structures

- feature structure
- attribute-value matrix
- feature matrix
- Shieber (1986), Pollard and Sag (1987), Johnson (1988), Carpenter (1992), King (1994)

Def. 1 (Feature Structure—Preliminary Version)
*A feature structure is a set of pairs of the form [*ATTRIBUTE *value].*

ATTRIBUTE *is an element of the set of feature names ATTR.*

The component value *is*

- *atomic (a string)*
- *or again a feature structure.*

Feature Structures – Examples

a simple feature structure:

$$\begin{bmatrix} \text{A1} & \textit{W1} \\ \text{A2} & \textit{W2} \\ \text{A3} & \textit{W3} \end{bmatrix}$$

a complex feature structure:

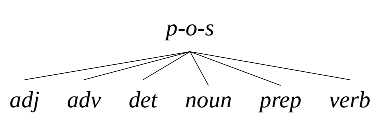
$$\begin{bmatrix} \text{A1} & \textit{W1} \\ \text{A2} & \begin{bmatrix} \text{A21} & \textit{W21} \\ \text{A22} & \begin{bmatrix} \text{A221} & \textit{W221} \\ \text{A222} & \textit{W222} \end{bmatrix} \end{bmatrix} \\ \text{A3} & \textit{W3} \end{bmatrix}$$

Types

- feature structures are of a certain type
- the type is written in *italics*:

$$\begin{bmatrix} \text{A1} & \textit{W1} \\ \textit{type} & \end{bmatrix}$$

- types are organized in hierarchies
- example: part of speech



Structure Sharing

A1 and A2 are token-identical:

$$\begin{bmatrix} \text{A1} & \boxed{1} \begin{bmatrix} \text{A3} & \textit{W3} \end{bmatrix} \\ \text{A2} & \boxed{1} \end{bmatrix}$$

Identity of values is marked by boxes

similar to variables

our agreement example

S $\rightarrow$ NP(Agr), VP(Agr)

rewritten with feature descriptions:

[CAT S] $\rightarrow$ [CAT NP, AGR $\boxed{1}$], [CAT VP, AGR $\boxed{1}$]

Valence and Grammar Rules: PSG

- huge amount of grammar rules:

VP	→	V	sleep
VP	→	V, NP	love
VP	→	V, PP	talk about
VP	→	V, NP, NP	give X Y
VP	→	V, NP, PP	give Y to X

- verbs have to be used with an appropriate rule
- subcategorization is encoded twice: in rules and in lexical entries

Valence and Grammar Rules: HPSG

- complements are specifi ed as complex categories in the lexical representation of the head
- like Categorial Grammar
- verb / subject / subcat

verb	subject	subcat
sleep	< NP >	< >
love	< NP >	< NP >
talk	< NP >	< PP >
give	< NP >	< NP, NP >
give	< NP >	< NP, PP >

- specifi c rules for head complement combinations:

V[SUBCAT [1]]	→	V[SUBCAT [1] ⊕ < [2] >] [2]
N[SUBCAT [1]]	→	N[SUBCAT [1] ⊕ < [2] >] [2]
A[SUBCAT [1]]	→	A[SUBCAT [1] ⊕ < [2] >] [2]
P[SUBCAT [1]]	→	P[SUBCAT [1] ⊕ < [2] >] [2]

- generalized, abstract schema (H = head):

  H[SUBCAT [1]] → H[SUBCAT [1] ⊕ < [2] >] [2]

Representation of Valence in Feature Descriptions

- a lexical entry consists of:

  gibt (‘gives’ finite form):

PHON	⟨ *gibt* ⟩
PART-OF-SPEECH	*verb*
SUBCAT	⟨ NP[*nom*], NP[*acc*], NP[*dat*] ⟩

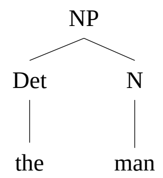
  - phonological information
  - information about part of speech
  - valence information: a list of feature descriptions
- NP[*nom*] is an abbreviation for a feature description

Representation of Grammar Rules (I)

- same description inventory for
  - morphological schemata,
  - lexical entries, and
  - phrasal schemata

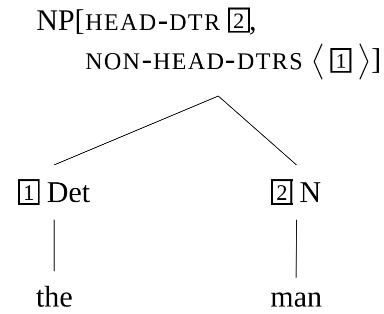
  everything is modeled in feature structures
- distinction between immediate dominance and linear precedence
- dominance is encoded in the daughter features of a structure (heads, non-heads)
- precedence is contained implicitly in the PHON value of a sign

Part of the Structure in Feature Structure Representation – PHON Values (I)



$$\begin{bmatrix} \text{PHON} & \langle \textit{the man} \rangle \\ \text{HEAD-DTR} & \begin{bmatrix}\text{PHON} \ \langle \textit{man}\rangle\end{bmatrix} \\ \text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix}\text{PHON} \ \langle \textit{the}\rangle\end{bmatrix} \right\rangle \end{bmatrix}$$

Tree with DTRS Values (I)



Representation of Grammar Rules (II)

- dominance rule:

Schema 1 (Head Complement Schema (binary branching))

$$\begin{bmatrix} \text{SUBCAT} \ \boxed{1} & \\ \text{HEAD-DTR} & \begin{bmatrix} \text{SUBCAT} \ \boxed{1} \oplus \left\langle \boxed{2} \right\rangle \\ \textit{sign} \end{bmatrix} \\ \text{NON-HEAD-DTRS} & \left\langle \boxed{2} \right\rangle \\ \textit{head-complement-structure} & \end{bmatrix}$$

$\oplus$ stands for *append*, i.e., a relation that concatenates two lists

- alternative formulation, similar to $\overline{\text{X}}$-Schema:

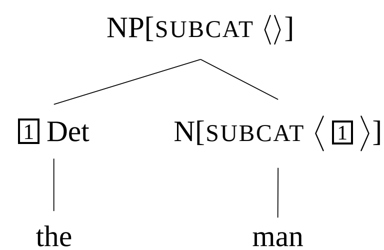
  H[SUBCAT $\boxed{1}$] $\rightarrow$ H[SUBCAT $\boxed{1} \oplus < \boxed{2} >$] $\boxed{2}$

- possible instantiation:

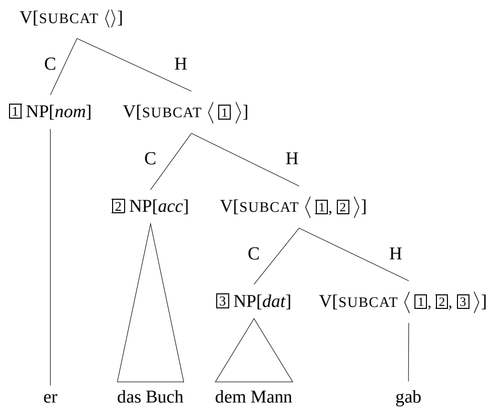
  N[SUBCAT $\boxed{1}$] $\rightarrow$ Det N[SUBCAT $\boxed{1} \oplus <$ Det $>$]

  V[SUBCAT $\boxed{1}$] $\rightarrow$ V[SUBCAT $\boxed{1} \oplus <$ NP[*dat*] $>$] NP[*dat*]

An Example



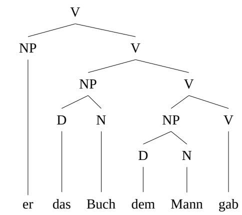
A More Complex Example



Binary Branching Head Complement Structure for ‘He gave the man the book.’

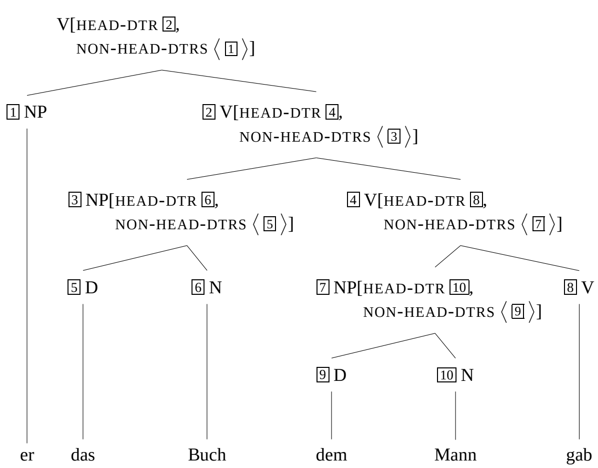
H = Head, C = Complement (= Non-Head)

Representation with Feature Structure – PHON Values (II)



PHON ⟨ *dem Mann gab* ⟩
HEAD-DTR [PHON ⟨ *gab* ⟩]
NON-HEAD-DTRS ⟨ [PHON ⟨ *dem Mann* ⟩
  HEAD-DTR [PHON ⟨ *Mann* ⟩]
  NON-HEAD-DTRS ⟨ [PHON ⟨ *dem* ⟩] ⟩] ⟩

Tree with DTRS Values (II)



Representation with Feature Structure – PHON values (III)

PHON ⟨ *er das Buch dem Mann gab* ⟩
HEAD-DTR [PHON ⟨ *das Buch dem Mann gab* ⟩
  HEAD-DTR [PHON ⟨ *dem Mann gab* ⟩
    HEAD-DTR [PHON ⟨ *gab* ⟩]
    NON-HEAD-DTRS ⟨ [PHON ⟨ *dem Mann* ⟩
      HEAD-DTR [PHON ⟨ *Mann* ⟩]
      NON-HEAD-DTRS ⟨ [PHON ⟨ *dem* ⟩] ⟩] ⟩]
  NON-HEAD-DTRS ⟨ [PHON ⟨ *das Buch* ⟩
    HEAD-DTR [PHON ⟨ *Buch* ⟩]
    NON-HEAD-DTRS ⟨ [PHON ⟨ *das* ⟩] ⟩] ⟩]
NON-HEAD-DTRS ⟨ [PHON ⟨ *er* ⟩] ⟩

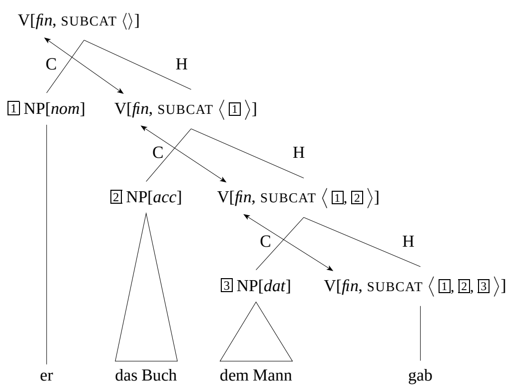
Representation in Feature Structures (Part)

PHON ⟨ *dem Mann, gab* ⟩
SUBCAT [1]
HEAD-DTR [PHON ⟨ *gab* ⟩, SUBCAT [1] ⟨ NP[*nom*], NP[*acc*] ⟩ ⊕ ⟨ [2] ⟩]
NON-HEAD-DTRS ⟨ [2] [PHON ⟨ *dem Mann* ⟩, P-O-S *noun*, SUBCAT ⟨⟩, HEAD-DTR . . ., NON-HEAD-DTRS . . ., *head-complement-structure*] ⟩
head-complement-structure

Representation in Feature Structures (Part)

PHON ⟨ *er, das Buch, dem Mann, gab* ⟩
SUBCAT [1]
HEAD-DTR [PHON ⟨ *das Buch, dem Mann, gab* ⟩, SUBCAT [1] ⟨⟩ ⊕ ⟨ [2] ⟩, *head-complement-structure*]
NON-HEAD-DTRS ⟨ [2] [PHON ⟨ *er* ⟩, P-O-S *noun*, SUBCAT ⟨⟩, HEAD-DTR . . ., NON-HEAD-DTRS . . ., *head-complement-structure*] ⟩
head-complement-structure

Projection of Head Properties



- head is the fi nite verb
- fi niteness of the verb is marked morphologically (*gab* = *gave*)
- information about fi niteness and part of speech is needed at the top node → projection

Representation in Feature Descriptions: the HEAD Value

- possible feature geometry:

  PHON *list of phonemes*
  P-O-S *p-o-s*
  VFORM *vform*
  SUBCAT *list*

- more structure, grouping information together for projection:

  PHON *list of phonemes*
  HEAD [P-O-S *p-o-s*, VFORM *vform*]
  SUBCAT *list*

Different Heads Project Different Features

- VFORM is appropriate only for verbs
- adjectives and nouns project case
- possability: one structure with all features:

$$\begin{bmatrix} \text{P-O-S} & \textit{p-o-s} \\ \text{VFORM} & \textit{vform} \\ \text{CASE} & \textit{case} \end{bmatrix}$$

  for verbs *case* is not fi lled in

  for nouns *vform* is not fi lled in

- better solution: different types of feature structures
  - for verbs

    $$\begin{bmatrix} \text{VFORM} & \textit{vform} \\ \textit{verb} & \end{bmatrix}$$

  - for nouns

    $$\begin{bmatrix} \text{CASE} & \textit{case} \\ \textit{noun} & \end{bmatrix}$$

A Lexical Entry with Head Features

- a lexical entry consists of:

  gibt ('gives' finite form):

$$\begin{bmatrix} \text{PHON} & \langle \textit{gibt} \rangle \\ \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{fin} \\ \textit{verb} & \end{bmatrix} \\ \text{SUBCAT} & \left\langle \text{NP}[\textit{nom}], \text{NP}[\textit{acc}], \text{NP}[\textit{dat}] \right\rangle \end{bmatrix}$$

  - phonological information
  - head information (part of speech, verb form, . . .)
  - valence information: a list of feature descriptions

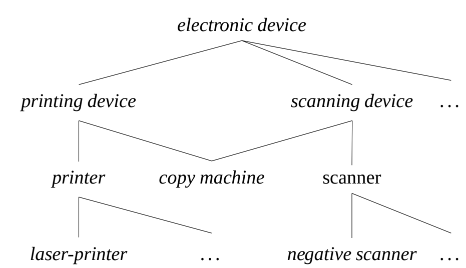
Head Feature Principle (HFP)

- In a headed structure the head features of the mother are token-identical to the head features of the head daughter.

$$\begin{bmatrix} \text{HEAD } \boxed{1} \\ \text{HEAD-DTR}|\text{HEAD } \boxed{1} \\ \textit{headed-structure} \end{bmatrix}$$

- encoding of principles in the type hierarchy: Krieger (1994a) and Sag (1997)
- *head-complement-structure* inherits constraints of *headed-structure*

Types: A Non-Linguistic Example for Multiple Inheritance



properties of and constraints on types are inherited from supertypes

possible to capture generalizations: general constraints are stated at high types

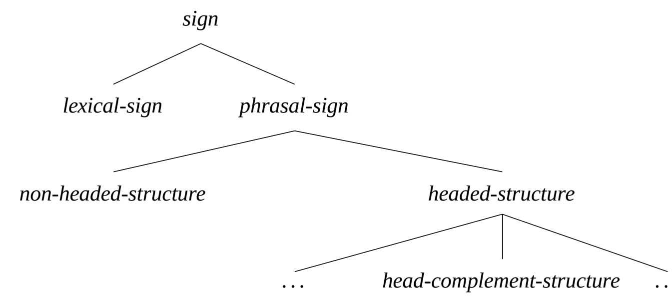
more special types inherit this information from their supertypes

nonredundant representation of information

Linguistic Generalizations in the Type Hierarchy

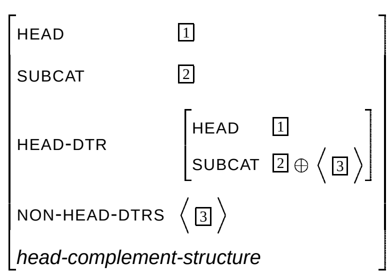
- types are arranged in a hierarchy
- the most general type is at the top
- information about properties of an object of a certain type are specified in the definition of the type
- subtypes inherit these properties
- example: entry in an encyclopedia. references to superconcepts, no repetition of the information that is stated at the superconcept already
- the upper part of a type hierarchy is relevant for all languages (Universal Grammar)
- more specific types may be specific for classes of languages or for one particular language

Type Hierarchy for *sign*



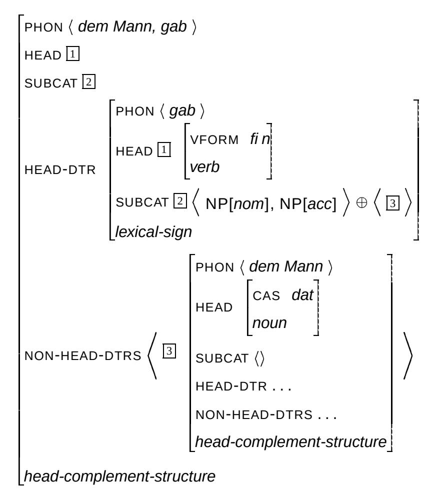
all subtypes of *headed-structure* inherit the constraints

Head Complement Schema + Head Feature Principle



Type *head-complement-structure* with information inherited from *headed-structure*

Head Complement Structure with Head Information Shared



Semantics

- Pollard and Sag (1987) and Ginzburg and Sag (2001) assume Situation Semantics (Barwise and Perry, 1983; Cooper, Mukai and Perry, 1990; Devlin, 1992)
- some recent publications use Minimal Recursion Semantics (Copestake, Flickinger and Sag, 1997)
- I will use Situation Semantics.

Individuals, Circumstances and Situations

- persistent things that belong to the causal order of the world, objects that we can track perceptually and affect by acting upon them: individuals (*Karl*, *the woman*, *the fear*, *the promise*)
- known facts: relations and properties (properties = relations with arity one)
  - zero: *rain*
  - one: *die*
  - two: *love*
  - three: *give*
  - four: *buy*
- semantic roles: Fillmore (1968, 1977), Kunze (1991)
  AGENT, PATIENT, EXPERIENCER, SOURCE, GOAL, THEME, LOCATION, TRANS-OBJ, INSTRUMENT, MEANS, and PROPOSITION
- roles are needed in order to capture generalizations: linking

Parameterized State of Affairs

- State of Affairs: *state of affairs* (*soa*)
- Verb: $\ll beat, agent : X, patient : Y; 1 \gg$
- Adjective: $\ll red, theme : X; 1 \gg$
- Noun: $\ll man, instance : X; 1 \gg$
- parameterized state of affairs (*psoa*)
- Verb

(14) The man beats the dog.

$\ll beat, agent : X, patient : Y; 1 \gg$
$X | \ll man, instance : X; 1 \gg,$
$Y | \ll dog, instance : Y; 1 \gg$

- Adjective

(15) The girl is smart.

$\ll smart, theme : X; 1 \gg$
$X | \ll girl, instance : X; 1 \gg$

Circumstances and Feature Structure Representations

$\ll beat, agent : X, patient : Y; 1 \gg$

$$\begin{bmatrix} \text{AGENT} & X \\ \text{PATIENT} & Y \\ \textit{beat} & \end{bmatrix}$$

$\ll man, instance : X; 1 \gg$

$$\begin{bmatrix} \text{INST} & X \\ \textit{man} & \end{bmatrix}$$

$\ll woman, instance : X; 0 \gg$

$$\begin{bmatrix} \text{ARG} & \begin{bmatrix} \text{INST} & X \\ \textit{woman} & \end{bmatrix} \\ \textit{neg} & \end{bmatrix}$$

Representation in Feature Descriptions: the CONT value

- possible feature geometry (CONT = CONTENT):

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes} \\ \text{HEAD} & \textit{head} \\ \text{SUBCAT} & \textit{list} \\ \text{CONT} & \textit{cont} \end{bmatrix}$$

- more structure, separation of syntactic and semantic information (CAT = CATEGORY)

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes} \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \textit{head} \\ \text{SUBCAT} & \textit{list} \\ \textit{cat} & \end{bmatrix} \\ \text{CONT} & \textit{cont} \end{bmatrix}$$

- → sharing of syntactic information can be expressed easily
- example: symmetric coordination: the CAT values of conjuncts are identical

(16) a. the man and the woman
b. He knows and loves this record.
c. He is stupid and arrogant.

The Semantic Contribution of Nominal Objects

- Index (like discourse referents in DRT (Kamp and Reyle, 1993))
- Restrictions

$$\begin{bmatrix} \text{PHON} & \langle \textit{book} \rangle \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{noun}\end{bmatrix} \\ \text{SUBCAT} & \left\langle \text{DET} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{IND} & \boxed{1} \begin{bmatrix} \text{PER} & \textit{3} \\ \text{NUM} & \textit{sg} \\ \text{GEN} & \textit{neu} \end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix} \text{INST} & \boxed{1} \\ \textit{book} & \end{bmatrix} \right\} \end{bmatrix} \end{bmatrix}$$

- person, number, and gender are important for resolving references:

(17) a. The woman$_i$ bought a table$_j$. She$_i$ likes it$_j$.
b. Die Frau$_i$ hat einen Tisch$_j$ gekauft. Sie$_i$ mag ihn$_j$.

Abbreviations

$$\text{NP}_{[3,sg,fem]} \quad \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{noun}\end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT|IND} & \begin{bmatrix} \text{PER} & \textit{3} \\ \text{NUM} & \textit{sg} \\ \text{GEN} & \textit{fem} \end{bmatrix} \end{bmatrix}$$

$$\text{NP}_{\boxed{1}} \quad \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{noun}\end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{IND} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

$$\overline{\text{N}}\text{: } \boxed{1} \quad \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{noun}\end{bmatrix} \\ \text{SUBCAT} & \left\langle \text{DET} \right\rangle \end{bmatrix} \\ \text{CONT} & \boxed{1} \end{bmatrix}$$

The Feature Structure Representation of Circumstances

$\ll beat, agent: X, patient: Y; 1 \gg$
$X | \ll man, instance: X; 1 \gg$,
$Y | \ll dog, instance: Y; 1 \gg$

$$\begin{bmatrix} \text{AGENT} & \boxed{1} \\ \text{PATIENT} & \boxed{2} \\ \textit{beat} & \end{bmatrix}$$

$$\begin{bmatrix} \text{IND} & \boxed{1} \begin{bmatrix} \text{PER} & \textit{3} \\ \text{NUM} & \textit{sg} \\ \text{GEN} & \textit{mas} \end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix} \text{INST} & \boxed{1} \\ \textit{man} & \end{bmatrix} \right\} \end{bmatrix} \qquad \begin{bmatrix} \text{IND} & \boxed{2} \begin{bmatrix} \text{PER} & \textit{3} \\ \text{NUM} & \textit{sg} \\ \text{GEN} & \textit{neu} \end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix} \text{INST} & \boxed{2} \\ \textit{dog} & \end{bmatrix} \right\} \end{bmatrix}$$

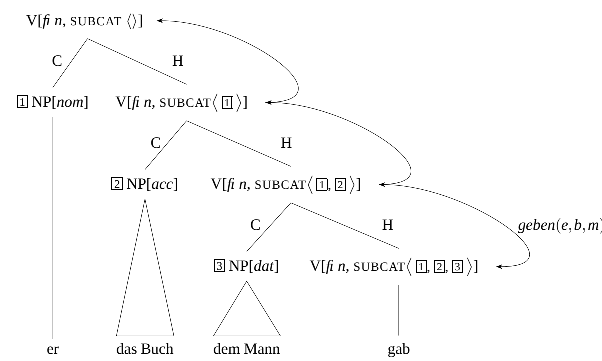
Representation in Feature Descriptions and Linking

- linking between valence and semantic contribution
- type-based
- various valance/linking patterns

gibt (finite Form):

$$\begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{fin} \\ \textit{verb} & \end{bmatrix} \\ \text{SUBCAT} & \left\langle \text{NP}[\textit{nom}]_{\boxed{1}}, \text{NP}[\textit{acc}]_{\boxed{2}}, \text{NP}[\textit{dat}]_{\boxed{3}} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{AGENT} & \boxed{1} \\ \text{THEME} & \boxed{2} \\ \text{GOAL} & \boxed{3} \\ \textit{geben} & \end{bmatrix} \end{bmatrix}$$

Projection of the Semantic Contribution of the Head



Semantics Principle (preliminary version)

In headed structures the content of the mother is identical to the content of the head daughter.

$$\begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{HEAD-DTR}|\text{CONT} & \boxed{1} \end{bmatrix}$$

Head Complement Schema + HFP + SemP

$$\begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{SUBCAT} & \boxed{2} \end{bmatrix} \\ \text{CONT} & \boxed{3} \\ \text{HEAD-DTR} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{SUBCAT} & \boxed{2} \oplus \left\langle \boxed{4} \right\rangle \end{bmatrix} \\ \text{CONT} & \boxed{3} \end{bmatrix} \\ \text{NON-HEAD-DTRS} & \left\langle \boxed{4} \right\rangle \\ \textit{head-complement-structure} & \end{bmatrix}$$

type *head-complement-structure* with information that is inherited from *headed-structure* and Semantics Principle

Outline

- Why Syntax? / Phrase Structure Grammars
- The Formalism
- Valence and Grammar Rules
- Complementation
- Semantics
- **Adjunction**
- The Lexicon
- Constituent Order (Local Dependencies)
- Nonlocal Dependencies
- Complex Predicates

Complements vs. Adjuncts

Examples for adjuncts:

adjectives	a *smart* woman
relative clauses	the man, *who Kim loves*,
	the man, *who loves Kim*,
Adverbs	Karl snores *loudly*.

- adjuncts do not fi ll a semantic role
- adjuncts are optional
- adjuncts can be iterated (18a), complements cannot (18b)

(18) a. a smart beautiful woman
b. * The man the man sleeps.

Adjunction

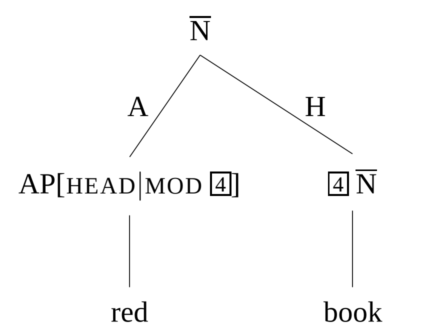
- adjunct selects head via MODIFIED

(19) the red book

$$\begin{bmatrix} \text{PHON} & \langle \textit{red} \rangle \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{MOD} & \overline{\text{N}} \\ \textit{adj} & \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \end{bmatrix}$$

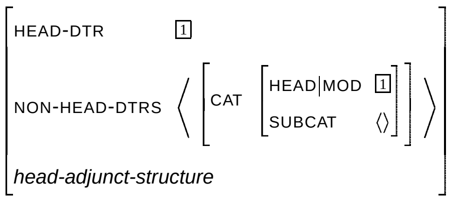
- adjectives select an almost saturated nominal projection
- elements that do not modify other elements have the MOD value *none*
- alternative:
  head contains description of all possible adjuncts (Pollard and Sag, 1987)
  problematic because of iteratability (Pollard and Sag, 1994)

Head Adjunct Structure (Selection)



H = Head, A = Adjunct (= Non-Head)

Schema 2 (Head Adjunct Schema (preliminary version))



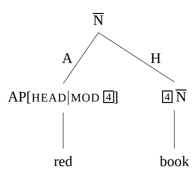
- the value of the selection feature of the adjunct (1) gets identified with the head daughter
- the adjunct must be saturated (SUBCAT ⟨⟩):

(20) a. the sausage in the cupboard
b. * the sausage in

Why is MOD a Head Feature?

- like adjectives, prepositional phrases can modify
- adjuncts must be saturated in order to be able to modify
- the feature that selects the head to be modifi ed has to be present at the maximal projection of the adjunct
- P + NP = PP
  PP modifi es $\overline{\text{N}}$
- MOD has to be present in the lexicon (P) and at a phrasal level (PP)
  project it explicitely or put it in a place that is projected anyway
  → head feature

The Semantic Contribution in Head Adjunct Structures



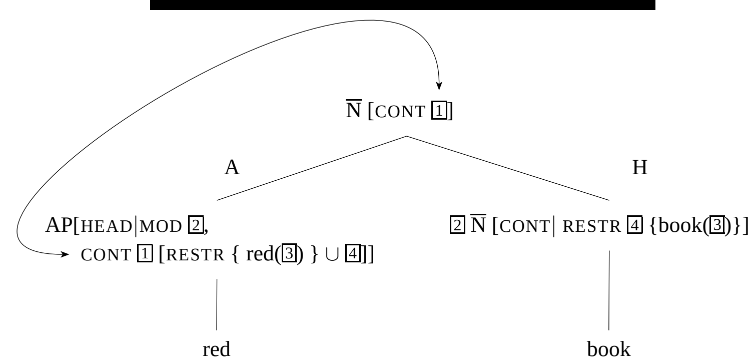
- From where does the semantic representation at the mother node come?
- the meaning of *book* is fi xed: book(X)
- possibility: projection of meaning representation of both daughters
- *red* (red(X)) + *book* (book(Y)) = red(X) & book(X)
- but:

(21) the alleged murderer

alleged (alleged(X)) + *murderer* (murderer(Y)) ≠ alleged(X) & murderer(X)

- alternative: representation of the meaning at the adjunct:
  The meaning of the mother node is encoded in the lexical entry for *red* and *alleged*.
  The meaning of the modifi ed head is integrated into the meaning of the modifi er.

Head Adjunct Structures (Selection and Semantics)



- the head adjunct schema identifi es the head with the MOD value of the adjunct daughter (2)
- modifi er has the meaning of the complete expression under CONT: { red(3) } ∪ 4
- semantic contribution of the phrase is projected from the modifi er (1)

Entry of the Adjective with Semantic Contribution

$$\begin{bmatrix} \text{PHON} & \langle \textit{red} \rangle \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{MOD} & \overline{\text{N}}: \begin{bmatrix}\text{IND} & \boxed{1}\\ \text{RESTR} & \boxed{2}\end{bmatrix} \\ \textit{adj} & \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{IND} & \boxed{1} \begin{bmatrix}\text{PER} & \textit{3}\\ \text{NUM} & \textit{sg}\end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix}\text{THEME} & \boxed{1}\\ \textit{red} & \end{bmatrix}\right\} \cup \boxed{2}\end{bmatrix}\end{bmatrix}$$

- adjective selects noun to be modifi ed via MOD →
  adjective can access CONT value of the noun (index and restrictions) →
  adjective may include restrictions ($\boxed{2}$) into its own semantic contribution
  identifi cation of indices ($\boxed{1}$) ensures that adjective and noun refer to the same discourse referent
- semantic contribution of the complete structure is projected from the adjunct

The Result of the Combination

$$\begin{bmatrix} \text{PHON} & \langle \textit{red book} \rangle \\ \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix}\textit{noun}\end{bmatrix} \\ \text{SUBCAT} & \left\langle \text{DET} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{IND} & \boxed{1} \begin{bmatrix}\text{PER} & \textit{3}\\ \text{NUM} & \textit{sg} \\ \text{GEN} & \textit{neu}\end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix}\text{THEME} & \boxed{1}\\ \textit{red} & \end{bmatrix}, \begin{bmatrix}\text{INST} & \boxed{1}\\ \textit{book} & \end{bmatrix}\right\} \end{bmatrix}\end{bmatrix}$$

meaning of *red book* is not represented in *book* but in the adjective →
projection of the semantic contribution form the adjunct

Projection of the Meaning in Head Adjunct Structures

$$\begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix}\text{CONT} & \boxed{1}\end{bmatrix} \right\rangle \\ \textit{head-adjunct-structure} & \end{bmatrix}$$

The Complete Head Adjunct Schema

Schema 3 (Head Adjunct Schema)

$$\begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{HEAD-DTR} & \boxed{2} \\ \text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD}|\text{MOD} & \boxed{2} \\ \text{SUBCAT} & \langle\rangle\end{bmatrix} \\ \text{CONT} & \boxed{1}\end{bmatrix} \right\rangle \\ \textit{head-adjunct-structure} & \end{bmatrix}$$

The Semantics Principle

In headed structures which are not head adjunct structures, the semantic contribution of the mother is identical to the semantic contribution of the head daughter.

$$\begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{HEAD-DTR}|\text{CONT} & \boxed{1} \\ \multicolumn{2}{l}{\textit{head-non-adjunct-structure}} \end{bmatrix}$$

In head adjunct structures, the semantic contribution of the mother is identical to the semantic contribution of the adjunct daughter.

$$\begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{NON-HEAD-DTRS} & \left\langle [\ \text{CONT}\ \boxed{1}\ ] \right\rangle \\ \multicolumn{2}{l}{\textit{head-adjunct-structure}} \end{bmatrix}$$

Headed structures (*headed-structure*) are subtypes of either *head-non-adjunct-structure* or *head-adjunct-structure*.

Valence in Head Adjunct Structures

book has the same valence like *red book*: a determiner is missing

adjunction does not change valence

valence information at the mother node is identical to the valence information of the head daughter

formal:

$$\begin{bmatrix} \text{CAT}|\text{SUBCAT}\ \boxed{1} \\ \text{HEAD-DTR}|\text{CAT}|\text{SUBCAT}\ \boxed{1} \\ \textit{head-non-complement-structure} \end{bmatrix}$$

In structures of type *head-non-complement-structure*, no argument gets saturated. The subcat value of the mother is identical to the subcat value of the head daughter.

Remark:
head-non-complement-structure and *head-complement-structure* have a complementary distribution in the type hierarchy.

I. e., all structures of type *headed-structure* that are not of type *head-complement-structure* are of type *head-non-complement-structure*.

Subcat Principle

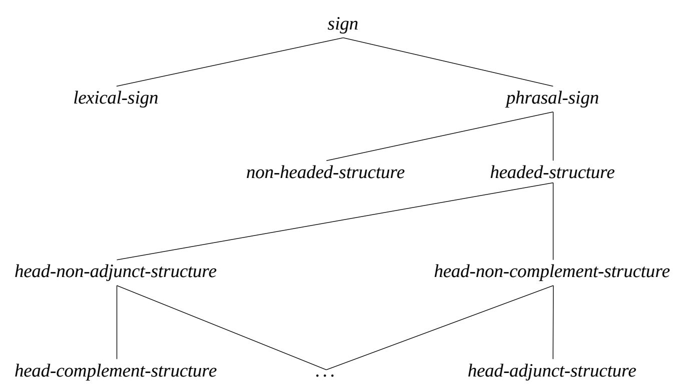
In headed structures the subcat list of the mother is the subcat list of the head daughter minus the complements that were realized as complement daughters.

$$\begin{bmatrix} \text{CAT}|\text{SUBCAT}\ \boxed{1} \\ \text{HEAD-DTR}|\text{CAT}|\text{SUBCAT}\ \boxed{1} \oplus \boxed{2} \\ \text{NON-HEAD-DTRS}\ \boxed{2}\ \textit{ne-list} \\ \textit{head-complement-structure} \end{bmatrix}$$

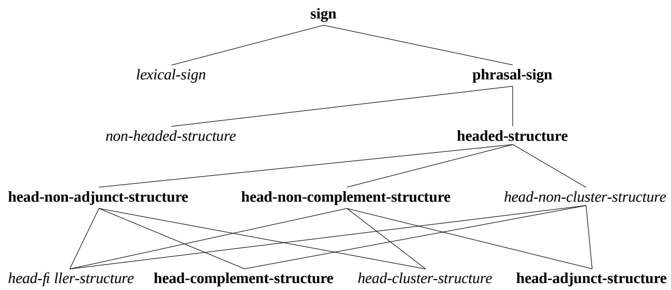
$$\begin{bmatrix} \text{CAT}|\text{SUBCAT}\ \boxed{1} \\ \text{HEAD-DTR}|\text{CAT}|\text{SUBCAT}\ \boxed{1} \\ \textit{head-non-complement-structure} \end{bmatrix}$$

Structures with head (*headed-structure*) are subtypes of either *head-complement-structure* or *head-non-complement-structure*.

Type Hierarchy for *sign*

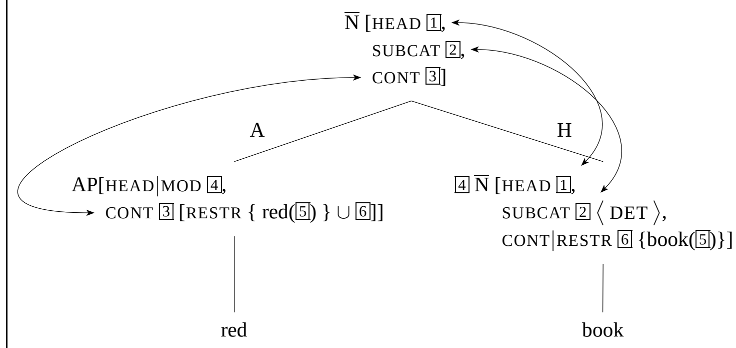


Type Hierarchy for *sign* (Overview)



Part under consideration is marked **bold**

Head Adjunct Structure (Selection, Semantics, HFP, ...)



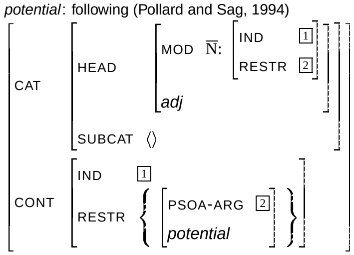
Encapsulating Modification

(22) Every soldier is a potential murderer.

(23) $\ll murderer, instance : X; 1 \gg$

(24) $\ll potential, arg: \{\ll murderer, instance : X; 1 \gg\}; 1 \gg$

potential: following (Pollard and Sag, 1994)



only approximation, for details see (Kasper, 1995) or (Müller, 1999)

The Locality of Selection

- with the present feature geometry, a head can access phonological form and internal structure of complements
- head may say: I want something that has a daughter with a PHON value *man*
- this possability should be excluded → modification in the feature geometry
- all features that can be selected are grouped together
- both syntactic and semantic information can be selected

The Locality of Selection: The Data Structure

- data structure of headed phrasal signs which we have now:

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes}\\ \text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{head}\\ \text{SUBCAT} & \textit{list}\\ \textit{cat} & \end{bmatrix}\\ \text{CONT} & \textit{cont}\\ \text{HEAD-DTR} & \textit{sign}\\ \text{NON-HEAD-DTRS} & \textit{list of signs}\end{bmatrix}$$

- new data structure with syntactic and semantic information under SYNTAX-SEMATICS (SYNSEM):

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes}\\ \text{SYNTAX-SEMANTICS} & \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD} & \textit{head}\\ \text{SUBCAT} & \textit{list of synsem-objects}\\ \textit{cat} & \end{bmatrix}\\ \text{CONT} & \textit{cont}\\ \textit{synsem} & \end{bmatrix}\\ \text{HEAD-DTR} & \textit{sign}\\ \text{NON-HEAD-DTRS} & \textit{list of signs}\end{bmatrix}$$

- only marked area is selected → no daughters or PHON
- elements in subcat-lists are *synsem* objects

Outline

The Lexicon

- lexicalization → enormous reduction of the number of immediate dominance rules
- lexical entries are very complex
- necessary to structure and crossclassify information → capturing of generalizations & avoiding redundancy
- type hierarchies and lexical rules

The Complexity of a Lexical Entry for a Count Noun

a lexical entry for the root of the count noun *Frau* ('woman'):

$$\begin{bmatrix} \text{PHON} & \langle \textit{frau} \rangle\\ \text{SYNSEM} & \begin{bmatrix}\text{CAT} & \begin{bmatrix}\text{HEAD} & [\textit{noun}]\\ \text{SUBCAT} & \langle \text{DET} \rangle\end{bmatrix}\\ \text{CONT} & \begin{bmatrix}\text{IND} & \boxed{1}\begin{bmatrix}\text{PER} & \textit{3}\\ \text{GEN} & \textit{fem}\end{bmatrix}\\ \text{RESTR} & \left\{\begin{bmatrix}\text{INST} & \boxed{1}\\ \textit{frau} & \end{bmatrix}\right\}\\ \textit{nom-obj} & \end{bmatrix}\end{bmatrix}\end{bmatrix}$$

just very few information is idiosyncratic

Factoring Out Common Information

a. all nouns

[SYNSEM [CAT|HEAD [*noun*] , CONT *nom-obj*]]

b. all referential non-pronominal nouns that take a determiner (in addition to a)

[SYNSEM [CAT [SUBCAT ⟨ DET ⟩] , CONT [IND [1] [PER *3*] , RESTR { [INST [1] , *psoa*], … }]]]

c. all feminine nouns (in addition to a und b)

[SYNSEM|CONT|IND|GEN *fem*]

Factoring Out Common Information

a lexical entry for a verb with dative complement:

helf- (‘help’, lexical entry (root)):

[PHON ⟨ *helf* ⟩ ,
SYNSEM [CAT [HEAD [SUBJ ⟨ NP[*nom*]$_{[1]}$ ⟩ , *verb*] , SUBCAT ⟨ NP[*dat*]$_{[2]}$ ⟩] ,
CONT [AGENT [1] , EXPERIENCER [2] , *help*]]]

a. all verbs

[SYNSEM [CAT|HEAD [*verb*] , CONT [*psoa*]]]

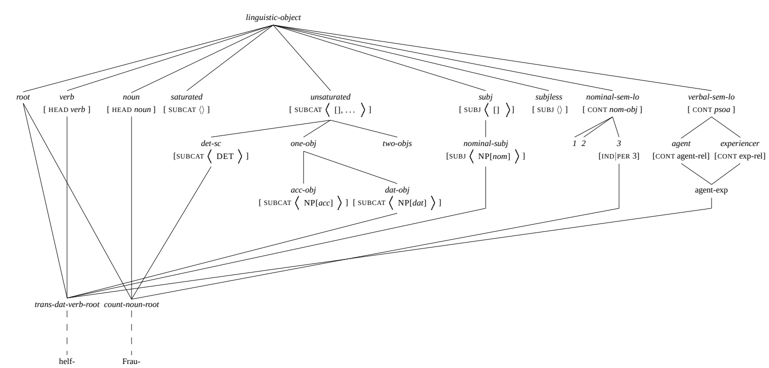
b. transitive verbs with a dative object (in addition to a)

[SYNSEM [CAT [HEAD|SUBJ ⟨ NP[*nom*] ⟩ , SUBCAT ⟨ NP[*dat*] ⟩]]]

c. all transitive verbs with AGENT and EXPERIENCER
(in addition to a)

[SYNSEM [CAT [HEAD|SUBJ ⟨ [CONT|IND [1]] ⟩ , SUBCAT ⟨ [CONT|IND [2]] ⟩] , CONT [AGENT [1] , EXPERIENCER [2] , *agent-exp*]]]

Part of an Example Type Hierarchy



- add appropriate paths:
  [SUBCAT ⟨⟩] stands for [SYNSEM|CAT|SUBCAT ⟨⟩]
- constraints will be inherited top down from the supertypes
- instances connected via dotted line

Examples for Lexical Entries

$$\begin{bmatrix} \text{PHON } \langle \textit{frau} \rangle \\ \text{CONT|RESTR } \left\{ \begin{bmatrix} \textit{frau} \end{bmatrix} \right\} \\ \textit{count-noun-root} \end{bmatrix}$$

$$\begin{bmatrix} \text{PHON } \langle \textit{helf} \rangle \\ \text{CONT } \begin{bmatrix} \textit{help} \end{bmatrix} \\ \textit{trans-dat-verb-root} \end{bmatrix}$$

Horizontal and Vertical Generalizations

- In type hierarchies we crossclassify linguistic objects (lexical entries, schemata).
- We express generalizations about classes of linguistic objects
- This enables us to say what certain words have in common.
  - *woman* and *man*
  - *woman* and *salt*
  - *woman* and *plan*
- But there are other regularities:
  - *kick* and *kicked* as used in *was kicked*
  - *love* and *loved* as used in *was loved*
- Words in the pairs could be put in the type hierarchy (as subtypes of intransitive and transitive), but than it would not be obvious that the valence change is due to the same process.

Lexical Rules

- Instead: Lexical Rules
  Jackendoff (1975), Williams (1981), Bresnan (1982b), Shieber, Uszkoreit, Pereira, Robinson and Tyson (1983),
  Flickinger, Pollard and Wasow (1985), Flickinger (1987), Copestake and Briscoe (1992), Meurers (2000)
- A lexical rule relates a description of the stem to an description of the passive form.
- different interpretations of the concept of lexical rules:
  (Meta Level Lexical Rules (MLR) vs. Description Level Lexical Rules (DLR))
  for a detailed discussion see Meurers (2000)

Lexical Rule for Passive in MLR-Notation

Lexical Rule for Passive:

$$\begin{bmatrix} \text{SYNSEM|CAT} \begin{bmatrix} \text{HEAD} \begin{bmatrix} \text{SUBJ } \langle \text{NP}[\textit{nom}] \rangle \end{bmatrix} \\ \text{SUBCAT } \langle \text{NP}[\textit{acc}]_{\boxed{1}} \rangle \oplus \boxed{2} \end{bmatrix} \\ \textit{stem} \end{bmatrix} \mapsto$$

$$\begin{bmatrix} \text{SYNSEM|CAT} \begin{bmatrix} \text{HEAD} \begin{bmatrix} \text{VFORM } \textit{passive-part} \\ \text{SUBJ } \langle \text{NP}[\textit{nom}]_{\boxed{1}} \rangle \end{bmatrix} \\ \text{SUBCAT } \boxed{2} \end{bmatrix} \\ \textit{lexical-sign} \end{bmatrix}$$

(25) a. The man kicks the dog.
b. The dog is kicked.

Conventions Regarding Lexical Rules

- All information that is not mentioned in the output sign is carried over from the input by convention.
- Example: Passive is meaning preserving. The CONT values of input and output are identical.

Linking-Information is preserved:

$$\begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD|SUBJ} & \langle \text{NP}[\textit{nom}]_{\boxed{1}} \rangle \\ \text{SUBCAT} & \langle \text{NP}[\textit{acc}]_{\boxed{2}} \rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{AGENT} & \boxed{1} \\ \text{PATIENT} & \boxed{2} \\ \textit{kick} & \end{bmatrix} \end{bmatrix} \mapsto \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD|SUBJ} & \langle \text{NP}[\textit{nom}]_{\boxed{2}} \rangle \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{AGENT} & \boxed{1} \\ \text{PATIENT} & \boxed{2} \\ \textit{kick} & \end{bmatrix} \end{bmatrix}$$

Lexical Rule for Passive in DLR-Notation

$$\begin{bmatrix} \text{SYNSEM|CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{passive-part} \\ \text{SUBJ} & \langle \text{NP}[\textit{nom}]_{\boxed{1}} \rangle \end{bmatrix} \\ \text{SUBCAT} & \boxed{2} \end{bmatrix} \\ \text{LEX-DTR} & \begin{bmatrix} \text{SYNSEM|CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{SUBJ} & \langle \text{NP}[\textit{nom}] \rangle \end{bmatrix} \\ \text{SUBCAT} & \langle \text{NP}[\textit{acc}]_{\boxed{1}} \rangle \oplus \boxed{2} \end{bmatrix} \\ \textit{stem} & \end{bmatrix} \\ \textit{passive-lexical-rule} & \end{bmatrix}$$

Lexical Rule for Passive in DLR-Notation with Morphology

$$\begin{bmatrix} \text{PHON} & f(\boxed{1}, ed) \\ \text{SYNSEM|CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{passive-part} \\ \text{SUBJ} & \langle \text{NP}[\textit{nom}]_{\boxed{2}} \rangle \end{bmatrix} \\ \text{SUBCAT} & \boxed{3} \end{bmatrix} \\ \text{LEX-DTR} & \begin{bmatrix} \text{PHON} & \boxed{1} \\ \text{SYNSEM|CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{SUBJ} & \langle \text{NP}[\textit{nom}] \rangle \end{bmatrix} \\ \text{SUBCAT} & \langle \text{NP}[\textit{acc}]_{\boxed{2}} \rangle \oplus \boxed{3} \end{bmatrix} \\ \textit{stem} & \end{bmatrix} \\ \textit{passive-lexical-rule} & \end{bmatrix}$$

- f is a relation that relates the PHON value of the LEX-DAUGHTER to its participle form (*walk* → *walked*)
- *lexical-sign* ≻ *passive-lexical-rule*
- DLRs are equivalent to unary projections
- since LRs are typed, generalizations over lexical rules are possible
- alternative to lexical rules: head affi x structures that are similar to binary syntactic structures

Head-Affix-Structures vs. Lexical Rule Based Approaches

- affix based approaches (Item and Arrangement)
  (Trost, 1991; Krieger and Nerbonne, 1993; Krieger, 1994b; van Eynde, 1994; Lebeth, 1994)
- Description-Level Lexical Rules (Item and Process)
  (Orgun, 1996; Riehemann, 1998; Ackerman and Webelhuth, 1998; Kathol, 1999, Koenig, 1999)

- in many cases grammar transformations are possible (Müller, 2000a)
- some consider it an advantage of the lexical rule-based approaches that they do not have to stipulate hundreds of empty affixes for zero inflection or conversion
- morphems that truncate stems are not needed in item and process approach

Outline

- Why Syntax? / Phrase Structure Grammars
- The Formalism
- Valence and Grammar Rules
- Complementation
- Semantics
- Adjunction
- The Lexicon
- **Constituent Order (Local Dependencies)**
- Nonlocal Dependencies
- Complex Predicates

Constituent Order: Languages with Fixed Constituent Order

- languages with rigid constituent order are unproblematic for PSGs

(26) The man gave the woman the book.

S $\rightarrow$ NP, VP

VP $\rightarrow$ V, NP, NP

Constituent Order: Languages with More Constituent Order Freedom

- But what about languages with more order freedom?
  In German all six permutations of the arguments are possible:

(27) a. Gab der Mann der Frau das Buch?
b. Gab der Mann das Buch der Frau?
c. Gab das Buch der Mann der Frau?
d. Gab das Buch der Frau der Mann?
e. Gab der Frau der Mann das Buch?
f. Gab der Frau das Buch der Mann?

- We need a lot of rules:

S $\rightarrow$ V, NP[nom], NP[acc], NP[dat]

S $\rightarrow$ V, NP[nom], NP[dat], NP[acc]

S $\rightarrow$ V, NP[acc], NP[nom], NP[dat]

S $\rightarrow$ V, NP[acc], NP[dat], NP[nom]

S $\rightarrow$ V, NP[dat], NP[nom], NP[acc]

S $\rightarrow$ V, NP[dat], NP[acc], NP[nom]

Abstracting Away From Linear Precedence

- a missing generalization about:

S $\rightarrow$ V, NP[nom], NP[acc], NP[dat]

S $\rightarrow$ V, NP[nom], NP[dat], NP[acc]

S $\rightarrow$ V, NP[acc], NP[nom], NP[dat]

S $\rightarrow$ V, NP[acc], NP[dat], NP[nom]

S $\rightarrow$ V, NP[dat], NP[nom], NP[acc]

S $\rightarrow$ V, NP[dat], NP[acc], NP[nom]

- Gazdar, Klein, Pullum and Sag (1985):
  separation of immediate dominance and linear precedence (ID/LP)
- no order of the daughters in a rule
- LP constraints on local trees, i.e., trees of depth one
- instead of six rules just one rule + no order restriction for the right hand side

S $\rightarrow$ V NP[nom] NP[acc] NP[dat]

Formulating Restrictions Again

- Now we have to much freedom:

  S → V NP[nom] NP[acc] NP[dat]

  The rule permits orders were the verb appears in the middle of the NPs.

(28) * Der Mann der Frau gibt ein Buch.
the man the woman gives a book

- We have to be able to restrict the position of the verb.
- Linearization Rules (simplifi ed):

  V[INITIAL+] < X

  X < V[INITIAL−]

Constituent Ordering in HPSG

- There is no surface order encoded in the dominance schemata:

Schema 4 (Head Complement Schema (binary branching))

$$\left[\begin{array}{ll} \text{SYNSEM|CAT|SUBCAT} & \boxed{1} \\ \text{HEAD-DTR} & \left[\begin{array}{l} \text{SYNSEM|CAT|SUBCAT } \boxed{1} \oplus \left\langle \boxed{2} \right\rangle \\ \textit{sign} \end{array}\right] \\ \text{NON-HEAD-DTRS} & \left\langle \boxed{2} \right\rangle \\ \multicolumn{2}{l}{\textit{head-complement-structure}} \end{array}\right]$$

- corresponds to head first or complement first serialization:

$$\text{H[SUBCAT } \boxed{1}] \rightarrow \text{H[SUBCAT } \boxed{1} \oplus < \boxed{2} >], \boxed{2}$$

$$\text{H[SUBCAT } \boxed{1}] \rightarrow \boxed{2}, \text{H[SUBCAT } \boxed{1} \oplus < \boxed{2} >]$$

The Constituent Order Principle

- A relational constraint computes the PHON value of the mother:

Constituent Order Principle adapted from (Pollard and Sag, 1987):

$$\left[\begin{array}{ll} \text{PHON} & \textit{order-constituents}(\boxed{1},\boxed{2}) \\ \text{HEAD-DTR} & \boxed{1} \\ \text{NON-HEAD-DTRS} & \boxed{2} \\ \multicolumn{2}{l}{\textit{headed-structure}} \end{array}\right]$$

- *order-constituents* may be very complex:
  If there is more than one non head daughter,
  we have to collect the PHON values.

The Simplest Case: Binary Branching Structures

In binary branching structures we have two possibilities:

- the head comes fi rst:

$$\left[\begin{array}{ll} \text{PHON} & \boxed{1} \oplus \boxed{2} \\ \text{HEAD-DTR} & \left[\text{PHON } \boxed{1}\right] \\ \text{NON-HEAD-DTRS} & \left\langle \left[\text{PHON } \boxed{2}\right] \right\rangle \\ \multicolumn{2}{l}{\textit{headed-structure}} \end{array}\right]$$

example:

$$\left[\begin{array}{ll} \text{PHON} & \langle \textit{loves, Karl} \rangle \\ \text{HEAD-DTR} & \left[\text{PHON } \langle \textit{loves} \rangle\right] \\ \text{NON-HEAD-DTRS} & \left\langle \left[\text{PHON } \langle \textit{Karl} \rangle\right] \right\rangle \\ \multicolumn{2}{l}{\textit{headed-structure}} \end{array}\right]$$

- the head comes last:

$$\left[\begin{array}{ll} \text{PHON} & \boxed{2} \oplus \boxed{1} \\ \text{HEAD-DTR} & \left[\text{PHON } \boxed{1}\right] \\ \text{NON-HEAD-DTRS} & \left\langle \left[\text{PHON } \boxed{2}\right] \right\rangle \\ \multicolumn{2}{l}{\textit{headed-structure}} \end{array}\right]$$

example:

$$\left[\begin{array}{ll} \text{PHON} & \langle \textit{Karl, sleeps} \rangle \\ \text{HEAD-DTR} & \left[\text{PHON } \langle \textit{sleeps} \rangle\right] \\ \text{NON-HEAD-DTRS} & \left\langle \left[\text{PHON } \langle \textit{Karl} \rangle\right] \right\rangle \\ \multicolumn{2}{l}{\textit{headed-structure}} \end{array}\right]$$

Linearization Rules in HPSG

- reference to feature values: P < N
  orders all prepositions to the left of nominal constituents

(29) a. in the bathroom
b. * the bathroom in

- reference to immediate dominance schema: FILLER < HEAD
- reference to both: HEAD[INITIAL+] < COMP
  orders all head daughters with the value + for the feature INITIAL to the left of their complements
- extension proposed by Uszkoreit (1987): violable, weighted LP rules
  different markedness of orders in (30):

(30) a. Gab der Mann der Frau das Buch.
b. Gab der Mann das Buch der Frau.
...

Relatively Free Constituent Order in the German Clause

How do we account for the possible orders in main clauses (31) and in embedded clauses (32)?

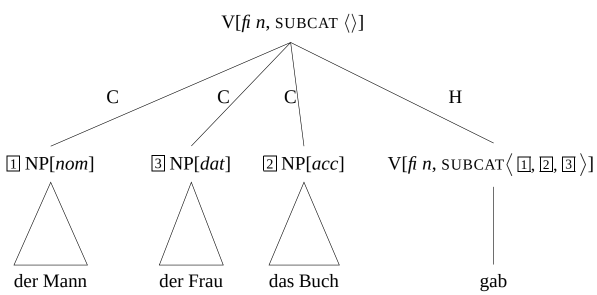
(31) a. Gab der Mann der Frau das Buch?
b. Gab der Mann das Buch der Frau?
c. Gab das Buch der Mann der Frau?
d. Gab das Buch der Frau der Mann?
e. Gab der Frau der Mann das Buch?
f. Gab der Frau das Buch der Mann?

(32) a. weil der Mann der Frau das Buch gab.
b. weil der Mann das Buch der Frau gab.
c. weil das Buch der Mann der Frau gab.
d. weil das Buch der Frau der Mann gab.
e. weil der Frau der Mann das Buch gab.
f. weil der Frau das Buch der Mann gab.

several proposals by Uszkoreit (1987), Pollard (1996),
Reape (1990, 1992, 1994), Kathol (1995, 2000),
Müller (1995, 1999, 2000a,b)

Flat Structures

- Uszkoreit (1987): flat structure



- complements are daughters of the same node
- all permutations are allowed

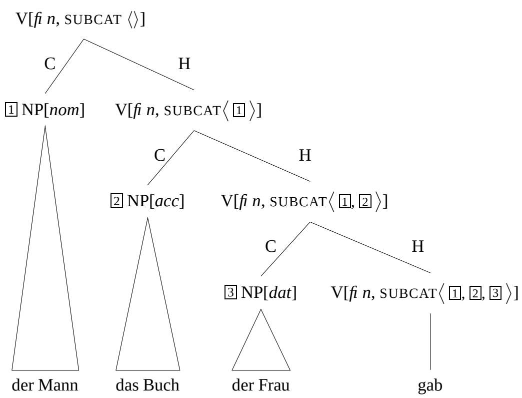
Problems with Flat Structures

- If one uses a phrase structure based backbone, number of rules quite big
- rules for
  - intransitive verbs
  - transitive verbs
  - ditransitive verbs
  - verbs with four arguments
  - verb in initial position: verbal complex at the right periphery of the clause
- adjuncts can be placed everywhere between the complements:

(33) a. Gab der Mann der Frau das Buch **gestern**?
b. Gab der Mann der Frau **gestern** das Buch?
c. Gab der Mann **gestern** der Frau das Buch?
d. Gab **gestern** der Mann der Frau das Buch?

- number of adjuncts is not restricted → number of rules is infi nite
  even with ad hoc restrictions huge set of rules
- Kasper (1994): underspecifi ed number of daughters, adjuncts and complements in the same tree, computation of the meaning by relational constraints (little programms)

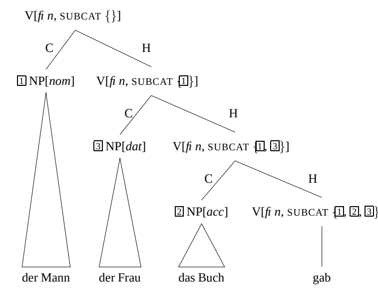
Binary Branching Structures



- trivial to account for the free appearance of adjuncts
- but the free ordering of complements → ?

A Subcat Set

- Gunji (1986), Hinrichs and Nakazawa (1989), Pollard (1996), and Engelkamp, Erbach and Uszkoreit (1992)



- an element of the subcat set is combined with the head
- the only condition is that combined elements are adjacent
- Problems:
  - spurious ambiguities if the head is in the middle
  - spurious ambiguities if nonlocal phenomena are involved

A Subcat List and a Relaxed Subcat Principle

- relaxation of the subcat principle
- the same problems as with the set-based approach

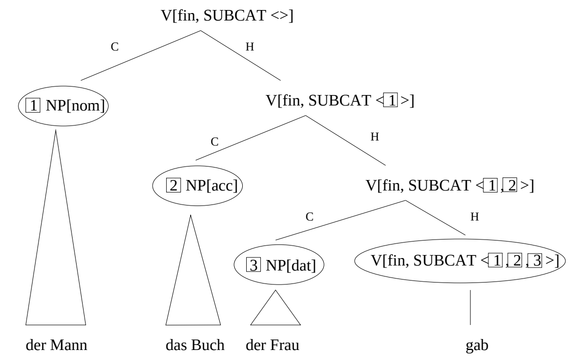
A Lexical Rule

- Uszkoreit (1986): lexical rule that takes a verb and computes lexical items with permuted elements in the subcat list
- at least six lexical items are licensed for a ditransitive verb like *geben* (up to 18!)

Discontinuous Constituents

- extension of the domain in which linearization constraints apply
- computation of phonology values is independend of constituent structure
- German: Reape (1991, 1992, 1994); Pollard, Kasper and Levine (1992, 1994); Kathol and Pollard (1995); Kathol (1995, 2000); Müller (1995, 1997, 1999); Richter and Sailer (2001)
- Warlpiri: Donohue and Sag (1999)
- Serbo-Croatian: Penn (1999)
- Dutch: Campbell-Kibler (2001)

Constituent Order Domains and Discontinuous Constituents



- circled nodes get inserted into a list: the linearization domain
- permutation of elements in these domains is restricted only by linearization rules
- linearization domains are head domains
- scrambling is local

Representation of Lexical Heads

$$\begin{bmatrix} \text{PHON} & \boxed{1} \\ \text{SYNSEM} & \boxed{2} \\ \text{DOM} & \left\langle \begin{bmatrix} \text{PHON} & \boxed{1} \\ \text{SYNSEM} & \boxed{2} \\ \text{DOM} & \langle\rangle \\ \textit{lexical-sign} & \end{bmatrix} \right\rangle \\ \textit{lexical-sign} & \end{bmatrix}$$

- a lexical head contains a description of itself in its domain
- adjunct and complement daughters are inserted into this list and are serialized relative to this element

Domain Formation

Non head daughter are inserted into the domain of their head:

$$\begin{bmatrix} \text{HEAD-DTR}|\text{DOM} & \boxed{1} \\ \text{NON-HEAD-DTRS} & \boxed{2} \\ \text{DOM} & \boxed{1} \bigcirc \boxed{2} \\ \textit{headed-structure} & \end{bmatrix}$$

The *shuffle* relation holds between three lists A, B, and C, iff C contains all elements of A and B and the order of the elements of A and the order of elements of B is preserved in C.

$$\begin{aligned} \langle a,b \rangle \bigcirc \langle c,d \rangle = & \langle a, b, c, d \rangle \lor \\ & \langle a, c, b, d \rangle \lor \\ & \langle a, c, d, b \rangle \lor \\ & \langle c, a, b, d \rangle \lor \\ & \langle c, a, d, b \rangle \lor \\ & \langle c, d, a, b \rangle \end{aligned}$$

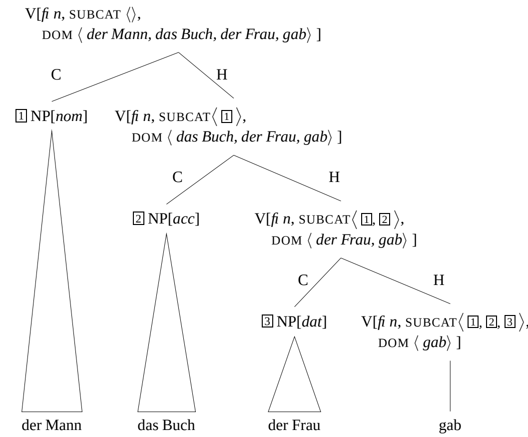
PHON Computation

Elements in DOM are ordered according to their surface order →

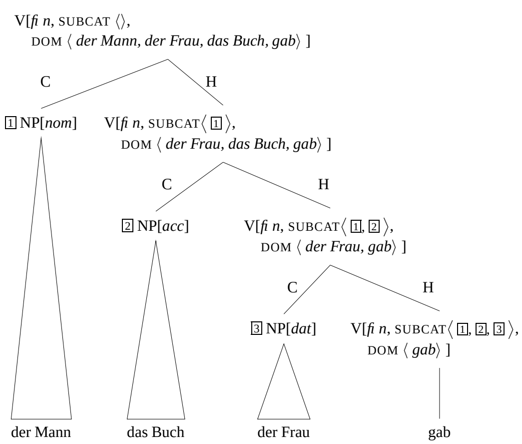
The PHON value of the mother is the concatenation of the PHON values of the domain elements.

$$\begin{bmatrix} \text{PHON} & \boxed{1} \oplus \ldots \oplus \boxed{n} \\ \text{DOM} & \left\langle \begin{bmatrix}\text{PHON} & \boxed{1} \\ \textit{sign} & \end{bmatrix}, \ldots, \begin{bmatrix}\text{PHON} & \boxed{n} \\ \textit{sign} & \end{bmatrix} \right\rangle \\ \textit{phrasal-sign} & \end{bmatrix}$$

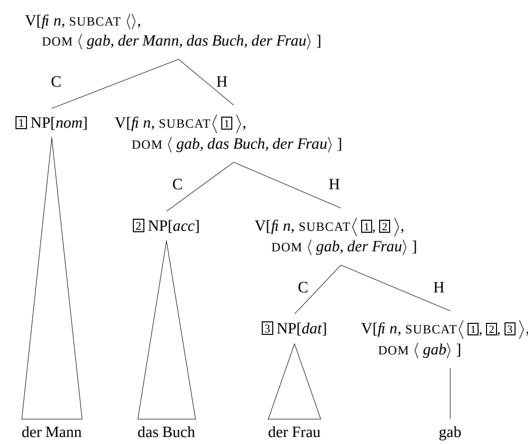
Example: Continuous Constituents



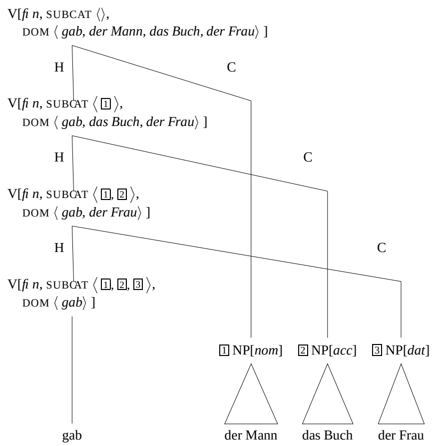
Example: Discontinuous Constituents / Permutation of NPs



Example: Discontinuous Constituents / Verb Placement



Verb Placement with Leaves in Surface Order



A Remark

- the dominance structuers for all sentences in (34) are the same:

(34) a. der Mann der Frau das Buch gab.
b. der Mann das Buch der Frau gab.
c. Gab der Mann das Buch der Frau.

- only the serialization of the elements in the order domains differs

Outline

- Why Syntax? / Phrase Structure Grammars
- The Formalism
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- Constituent Order (Local Dependencies)
- **Nonlocal Dependencies**
- Complex Predicates

Nonlocal Dependencies

- topicalization

(35) a. Bagels$_i$, [I like _$_i$].

_$_i$ stands for the gap or trace
Bagels$_i$ is the fi ller

- the dependencies are nonlocal, sentence boundaries may be crossed:

(36) a. Bagels$_i$, [I like _$_i$].
b. Bagels$_i$, [Sandy knows [I like _$_i$]].

- relative clauses

(37) The man who$_i$ Mary loves _$_i$ left.

- *wh* questions

(38) Who$_i$ did Kim claim _$_i$ left?

Data Structure: Grouping into Local/Non-Local Information

- grouping of the information into such that is locally relevant (LOCAL) and such that plays a role in nonlocal dependencies (NONLOCAL)

[PHON *list of phonemes*
  SYNSEM [LOC [CAT [HEAD *head*
                       SUBCAT *list of synsem objects*
                       cat]
                 CONT *cont*
                 loc]
           NONLOC *nonloc*
           synsem]
  sign]

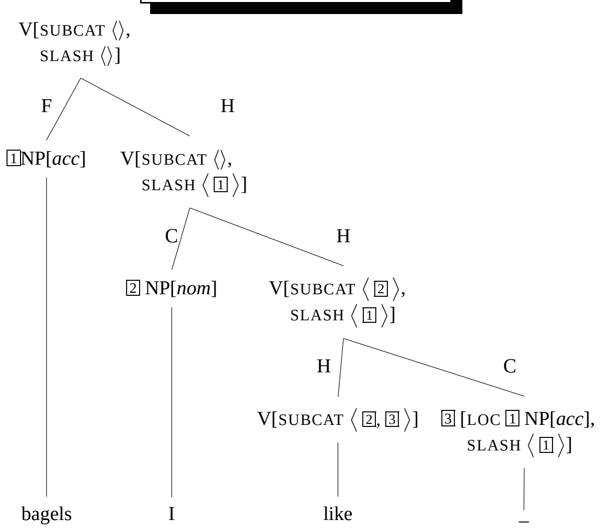
Data Strucutre for Nonlocal Information

- NONLOC value is structured further:

[QUE [*list of npros*]
  REL [*list of indices*]
  SLASH [*list of local structures*]
  nonloc]

- QUE: list of indices of question words (interrogative clauses)
- REL: list of indices of relative pronouns (relative clauses)
- SLASH: list of *local* objects (topicalization)
- The name SLASH is historical (GPSG).
- We will only consider SLASH.

Percolation of Nonlocal Information



The Trace

[PHON ⟨⟩
  SYNSEM [LOCAL 1
           NONLOCAL|SLASH ⟨ 1 ⟩]
  lexical-sign]

- no phonological contribution
- whatever is expected locally (1) is put into the SLASH list
- trace instantiated for complement of *like* = NP[*acc*]:

[PHON ⟨⟩
  SYNSEM [LOCAL 1 [CAT [HEAD [CAS *acc*
                                  noun]
                           SUBCAT ⟨⟩]]
           NONLOCAL|SLASH ⟨ 1 ⟩]
  lexical-sign]

Schema 5 (Head Filler Schema)

$$\begin{bmatrix} \text{NONLOC}|\text{SLASH}\ \langle\rangle \\ \text{HEAD-DTR}|\text{SYNSEM} \begin{bmatrix} \text{LOCAL} \begin{bmatrix} \text{CAT} \begin{bmatrix} \text{HEAD} \begin{bmatrix} \text{VFORM}\ \textit{fin} \\ \textit{verb} \end{bmatrix} \\ \text{SUBCAT}\ \langle\rangle \end{bmatrix} \end{bmatrix} \\ \text{NONLOC}|\text{SLASH}\ \langle \boxed{1} \rangle \end{bmatrix} \\ \text{NON-HEAD-DTRS}\ \left\langle \begin{bmatrix} \text{SYNSEM} \begin{bmatrix} \text{LOCAL}\ \boxed{1} \\ \text{NONLOC}|\text{SLASH}\ \langle\rangle \end{bmatrix} \end{bmatrix} \right\rangle \\ \textit{head-filler-structure} \end{bmatrix}$$

- the head daughter is a finite clause with a missing constituent ($\boxed{1}$)
- the non head daughter is the filler, i.e., corresponds to the missing constituent
- the gap is filled, the mother does not have any gaps → SLASH is empty

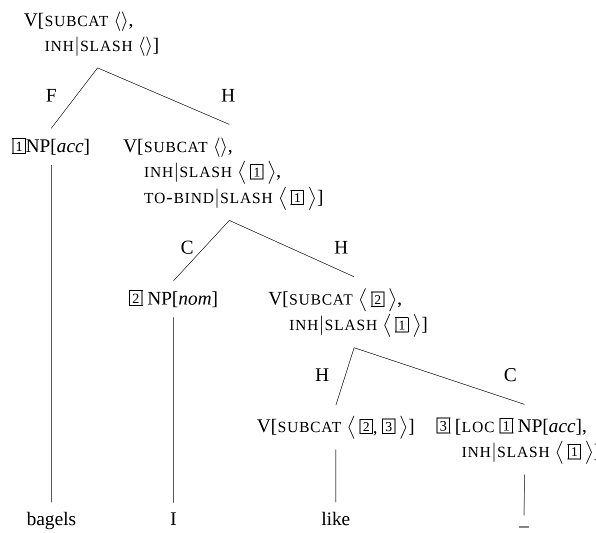
Important Points about the Analysis

- percolation of nonlocal information
- structure sharing →
  information simultaneously present at each node
- nodes in the middle of a nonlocal dependency can access it
  there are languages where elements inflect depending on whether a nonlocal depnedency passes the node they head

More Complex Examples: *tough* Movement

(39) a. John$_i$ is easy to please _$_i$.
b. * John is easy to please John.

- *to please* is a VP with a missing object (*We try [to please John].*
- adjective selects for a VP with something missing, i.e., something in SLASH
- this something is coreferent with the subject of *easy* which does surface
- *easy* lexically binds off the gap in the VP



Trace:

$$\begin{bmatrix} \text{PHON} & \langle\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{1} \\ \text{NONLOCAL} & \begin{bmatrix} \text{INHERITED} & \begin{bmatrix} \text{SLASH} & \langle \boxed{1} \rangle \end{bmatrix} \\ \text{TO-BIND} & \begin{bmatrix} \text{SLASH} & \langle\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \textit{lexical-sign} & \end{bmatrix}$$

Trace Instantiated for Complement of *like*:

$$\begin{bmatrix} \text{PHON} & \langle\rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{1} \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{CAS} & \textit{acc} \\ \textit{noun} & \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \end{bmatrix} \\ \text{NONLOCAL} & \begin{bmatrix} \text{INHERITED} & \begin{bmatrix} \text{SLASH} & \langle \boxed{1} \rangle \end{bmatrix} \\ \text{TO-BIND} & \begin{bmatrix} \text{SLASH} & \langle\rangle \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \textit{lexical-sign} & \end{bmatrix}$$

Nonlocal Feature Principle

For each nonlocal feature, the INHERITED value of the mother is the concatenation of the INHERITED values on the daughters minus the TO-BIND value on the head daughter.

Schema 6 (Head Filler Schema)

$$\begin{bmatrix} \text{HEAD-DTR}|\text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{fin} \\ \textit{verb} & \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \end{bmatrix} \end{bmatrix} \\ \text{NONLOC} & \begin{bmatrix} \text{INHER}|\text{SLASH} & \langle \ldots, \boxed{1}, \ldots \rangle \\ \text{TO-BIND}|\text{SLASH} & \langle \boxed{1} \rangle \end{bmatrix} \end{bmatrix} \\ \text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{LOCAL} & \boxed{1} \\ \text{NONLOC} & \text{INHER}|\text{SLASH} \ \langle\rangle \end{bmatrix} \end{bmatrix} \right\rangle \\ \textit{head-filler-structure} & \end{bmatrix}$$

Problems with Traces

Linguistic:

- coordination
  _ and _
- linearization (depending on assumptions made in the grammar)

(40) Dem Mann$_i$ hilft eine Frau _$_i$. vs. Dem Mann$_i$ hilft _$_i$ eine Frau.
the man$_{dat}$ helps a woman$_{nom}$ the man$_{dat}$ helps a woman$_{nom}$

- restriction to non heads

(41) a. [Der kluge Mann]$_i$ hat _$_i$ geschlafen.
the smart man has slept
'The smart man slept.'

b. * [Mann]$_i$ hat der kluge _$_i$ geschlafen.

Computational:

- depending on the parser:
  hypotheses of empty elements that are never used

(42) the _ man

Introduction of Nonlocal Dependencies

- trace
- unary projection
- lexical rule
- underspecified lexical entries and relational constraints

Grammar Transformation

Bar-Hillel, Perles and Shamir (1961):

$\overline{v} \rightarrow v, np$		$\overline{v} \rightarrow v, np$
$np \rightarrow \varepsilon$	$\Rightarrow$	$\overline{v} \rightarrow v$
$\overline{v} \rightarrow \overline{v}, adv$		$\overline{v} \rightarrow \overline{v}, adv$
$adv \rightarrow \varepsilon$		$\overline{v} \rightarrow \overline{v}$

$\text{H[SUBCAT X]} \rightarrow \text{H[SUBCAT X} \oplus \langle \text{Y} \rangle\text{], Y}$
$\text{Y} \rightarrow \varepsilon$

$\Rightarrow$

$\text{H[SUBCAT X]} \rightarrow \text{H[SUBCAT X} \oplus \langle \text{Y} \rangle\text{], Y}$
$\text{H[SUBCAT X]} \rightarrow \text{H[SUBCAT X} \oplus \langle \text{Y} \rangle\text{]}$

Schema 7 (SLASH Introduction Schema for Complements)

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{LOC|CAT} & \begin{bmatrix}\text{SUBCAT} & \boxed{1}\end{bmatrix} \\ \text{NONLOC} & \begin{bmatrix}\text{INHER|SLASH} & \langle \boxed{2} \rangle \oplus \boxed{3}\end{bmatrix} \end{bmatrix} \\ \text{HEAD-DTR} & \begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{LOC|CAT} & \begin{bmatrix}\text{SUBCAT} & \boxed{1} \oplus \langle \boxed{4} \rangle\end{bmatrix} \\ \text{NONLOC} & \begin{bmatrix}\text{INHER|SLASH} & \boxed{3}\end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \textit{head-comp-slash-structure} & \end{bmatrix}$$

$\boxed{4}$ stands for: $\begin{bmatrix} \text{LOC} & \boxed{2} \\ \text{NONLOC} & \begin{bmatrix}\text{INHER|SLASH} & \langle \boxed{2} \rangle\end{bmatrix} \\ \textit{synsem} & \end{bmatrix}$

$\boxed{6}$ is the SYNSEM value of a trace

Lexicon Transformation

$\bar{v} \rightarrow$ v-ditrans, np, np, np — v-ditrans $\rightarrow$ give
$\bar{v} \rightarrow$ v-trans, np, np — v-trans $\rightarrow$ love
$\bar{v} \rightarrow$ v-intrans, np — v-intrans $\rightarrow$ sleep
$\bar{v} \rightarrow$ v-subjless
np $\rightarrow \varepsilon$

$\Rightarrow$

$\bar{v} \rightarrow$ v-ditrans, np, np, np — v-ditrans $\rightarrow$ give
$\bar{v} \rightarrow$ v-trans, np, np — v-trans $\rightarrow$ love $\vee$ give
$\bar{v} \rightarrow$ v-intrans, np — v-intrans $\rightarrow$ sleep $\vee$ love $\vee$ give
$\bar{v} \rightarrow$ v-subjless — v-subjless $\rightarrow$ sleep $\vee$ love $\vee$ give

Lexicon Transformation

$V[\text{SUBCAT} \langle NP_1, NP_2, NP_3 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_1, NP_2 \rangle] \rightarrow$ love
$V[\text{SUBCAT} \langle NP_1 \rangle] \rightarrow$ sleep

$\Rightarrow$

$V[\text{SUBCAT} \langle NP_1, NP_2, NP_3 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_1, NP_2 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_1, NP_3 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_2, NP_3 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_1 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_2 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle NP_3 \rangle] \rightarrow$ give
$V[\text{SUBCAT} \langle\rangle] \rightarrow$ give

$V[\text{SUBCAT} \langle NP_1, NP_2 \rangle] \rightarrow$ love
$V[\text{SUBCAT} \langle NP_1 \rangle] \rightarrow$ love
$V[\text{SUBCAT} \langle NP_2 \rangle] \rightarrow$ love
$V[\text{SUBCAT} \langle\rangle] \rightarrow$ love

$V[\text{SUBCAT} \langle NP_1 \rangle] \rightarrow$ sleep
$V[\text{SUBCAT} \langle\rangle] \rightarrow$ sleep

The SLASH Introduction Lexical Rule

$$\begin{bmatrix} \text{SYNSEM} \begin{bmatrix} \text{LOC} & [\text{CAT|SUBCAT } \boxed{1} \oplus \langle \boxed{2} \rangle \oplus \boxed{3}] \\ \text{NONLOC} & [\text{INHER|SLASH } \boxed{4}] \end{bmatrix} \\ \textit{lexical-sign} \end{bmatrix} \rightarrow$$

$$\begin{bmatrix} \text{SYNSEM} \begin{bmatrix} \text{LOC} & [\text{CAT|SUBCAT } \boxed{1} \oplus \boxed{3}] \\ \text{NONLOC} & [\text{INHER|SLASH } \boxed{4} \oplus \langle \boxed{5} \rangle] \end{bmatrix} \\ \textit{lexical-sign} \end{bmatrix}$$

$\boxed{2}$ stands for: $\begin{bmatrix} \text{LOC} & \boxed{5} \\ \text{NONLOC} & [\text{INHER|SLASH } \langle \boxed{5} \rangle] \\ \textit{synsem} & \end{bmatrix}$

Lexicon Underspecification

Bouma, Malouf and Sag (2001)

- two lists:
  - Argument Structure
  - Dependents

Outline

Raising and Control

- verbs can embed other verbs or verbal projections:

(43) a. Kim seems to sleep.
b. Kim tries to sleep.

- raising verbs
  - do not assign a semantic role to the subject of the embedded element
  - allow embedding of predicates with an expletive subject / without a subject
  - subject or object of the higher verb is identical to the subject of the embedded verb
- control verbs
  - assign a semantic role
  - do not embed predicates with expletive subject or with no subject
  - one argument is coreferent with the subject of the embedded verb

Semantic Role

- the subject of the embedded verb fi lls a semantic role in the relation of the control verb

(44) a. Kim tries to sleep.
b. try(Kim, sleep(Kim))

- raising verbs: no semantic role for the subject of the embedded verb

(45) a. Kim seems to sleep.
b. seem(sleep(Kim))

$\rightarrow$ no selectional restrictions

- nevertheless *Kim* is the subject of *seem*
  - for English this is clear because of the position of *Kim*
  - subject verb agreement:

(46) a. The men seem to sleep.
b. * The men seem to sleeps.

Subjectless Constructions: Subjectless Verbs

- languages like German have verbs that may appear without a subject:

(47) weil dem Student vor der Prüfung graut.
because the student_{dat} before the exam dreads
'Because the student dreads the exam.'

- such predicates cannot be embedded under control verbs:

(48) * Der Professor versucht, dem Student vor der Prüfung zu grauen.
the professor tries the student before the exam to dread
Intended: 'The professor tries to make the student dread the exam.'

- the embedding under raising verbs is possible:

weil dem Student vor der Prüfung zu grauen schien.
because the student before the exam to dread seemed
'because the student seemed to dread the exam.'

Subjectless Constructions: Impersonal Passives

- another subjectless construction is the so-called impersonal passive

(49) a. Der Student arbeitet.
the student works

b. weil gearbeitet wurde.
because worked was
'because work was being done.'

- imperonal passives may not be embedded under control verbs:

(50) * Der Student versucht, gearbeitet zu werden.
the student tries worked to get
Intended: 'The student tries to work.' or 'The student tries to get the work done.'

- embedding under raising verbs is possible:

(51) Dort schien noch gearbeitet zu werden.
there seemed yet working to get
'Work seemed to still be being done there.'

The Embedding of Expletive Predicates

- control verbs have selectional restrictions → Embedding of weather verbs is excluded

(52) a. * He tries to rain.
b. * It tries to rain.
c. * He persuades it to rain.

- raising verbs allow the embedding of expletive predicates:

(53) a. It seems to rain.
b. He saw it rain.

Identity vs. Coindexing

- raising verbs: subject of the embedded verb is identical to the subject or obejct of the matrix verb, provided the embedded verb has a subject

(54) a. Karl sah es regnen.
Karl saw it_{expl} rain

b. ? Ich sah ihm schlecht werden.
I saw him_{dat} feel.sick become
'I saw him getting sick.'

- Are control verbs different?
- we will examine the following examples:

(55) a. Der Wächter sah den Einbrecher und seinen Helfer stehen bleiben.
the watchman saw the burglar and his $accomplice_{acc}$ stand remain
'The watchman saw the burglar and his accomplice stop running.'

b. Der Wächter zwang den Einbrecher und seinen Helfer stehen zu bleiben.
the watchman percuaded the burglar and his $accomplice_{acc}$ stand to remain
'The watchman persuaded the burglar and his accomplice to stop running.'

Case-Agreeing Adjuncts (I)

- Höhle (1983): the phrase *ein- nach d- ander-* ('one after the other') agrees with its antecedent in case, gender and number
- reference to the subject in a simple clause:

(56) a. [Die Türen]$_i$ sind [eine nach der anderen]$_i$ kaputt gegangen.
the $doors_{nom\,pl\,fem}$ are $one_{nom\,fem}$ after $the_{dat\,fem}$ other broke went
'The doors broke one after another.'

b. [Einer nach dem anderen]$_i$ haben wir$_i$ die Burschen runtergeputzt.
$one_{nom\,mas}$ after $the_{dat\,mas}$ other have we_{nom} the $lads_{acc}$ down.cleaned
'We took turns in bringing the lads down a peg or two.'

c. [Einen nach dem anderen]$_i$ haben wir [die Burschen]$_i$ runtergeputzt.
$one_{acc\,mas}$ after $the_{dat\,mas}$ other have we_{nom} the $lads_{acc\,pl\,mas}$ down.cleaned
'One after the other, we brought the lads down a peg or two.'

d. Ich ließ [die Burschen]$_i$ [einen nach dem anderen]$_i$ einsteigen.
I let the $lads_{acc\,pl\,mas}$ $one_{acc\,mas}$ after $the_{dat\,mas}$ other enter
'I let the lads get in (get started) one after the other.'

e. [Uns]$_i$ wurde [einer nach der anderen]$_i$ der Stuhl vor die Tür gesetzt.
us_{dat} was $one_{dat\,fem}$ after $the_{dat\,fem}$ other the chair before the door set
'We were given the sack one after the other.'

Case-Agreeing Adjuncts (II)

- reference to the object in embedded infi nitives:

(57) a. Er hat uns gedroht, [die Burschen$_i$ demnächst [einen nach dem anderen]$_i$
he has us threatened the lads$_{acc\,pl\,mas}$ soon one$_{acc\,mas}$ after the$_{dat\,mas}$ other
wegzuschicken.
away.to.send

'He threatened us that soon he would send the lads away one after the other.'

b. Er hat angekündigt, [uns]$_i$ dann [einer nach der anderen]$_i$ den Stuhl vor
he has announced us$_{dat}$ then one$_{dat\,fem}$ after the$_{dat\,fem}$ other the chair before
die Tür zu setzen.
the door to set

'He announced that he would then sack us one after the other.'

c. Es ist nötig, [die Fenster]$_i$, sobald es geht, [eins nach dem
it is necessary the windows$_{acc\,pl\,neu}$ as.soon it goes one$_{acc\,neu}$ after the$_{dat\,neu}$
anderen]$_i$ auszutauschen.
other to.exchange

'It is necessary to exchange the windows one after the other, as soon as possible.'

The Case of Non-Overt Subjects

- case-agreeing adjuncts with reference to subjects in embedded infi nitives can be used to determine their case (Höhle, 1983, Chapter 6)

(58) a. Ich habe [den Burschen]$_i$ geraten, im Abstand von wenigen Tagen [einer nach
I have the lads$_{dat\,pl\,mas}$ advised in.the distance of few days one$_{nom\,mas}$ after
dem anderen]$_i$ zu kündigen.
the$_{dat\,mas}$ other to hand.in.their.notice

'I advised the lads to hand in their notice one after the other, at intervals of a few days.'

b. [Die Türen sind viel zu wertvoll, um [eine nach der anderen]$_i$
the doors$_{nom\,pl\,fem}$ are much too precious COMPL one$_{nom\,fem}$ after the$_{dat\,fem}$ other
verheizt zu werden.
burnt to be

'The doors are much too precious to be burnt one after the other.'

- *ein- nach d- ander-* is not the subject since the subject is never realized in constructions with *zu* infi nitives
- but it refers to the subject
- *ein- nach d- ander-* has nominativ → the non-overt subject also
- in (58a) the case of the controlling NP *den Burschen* ('the lads') is dative, the controlled subject is nominative
- subject of the embedded verb cannot be identical with the object of the control verb

Identity in Control Constructions?

- appart from differences in case we have differing categories:

(59) Kim appealed to Sandy to cooperate. (Pollard and Sag, 1994)

(60) Die Lehrer, von denen erwartet wird, diesen aufgeputschten
the teachers from whom expected gets these doped
Kohlehydratkolossen etwas beizubringen, verdienen
carbohydrate.giants something to.teach deserve
jedermanns Anteilnahme. (Max Goldt)
everyone's sympathy

'The teachers who are expected to teach these doped carbohydrate monsters deserve universal sympathy.'

- a PP controls the subject noun phrase

Raising Verbs: Agreement and Identity

- raising verbs are diferent:

(61) a. Der Wächter sah den Einbrecher und seinen Helfer einen nach
the watchman saw the burglar and his accomplice$_{acc}$ one$_{acc}$ after
dem anderen weglaufen.
the other run.away

'The watchman saw the burglar and his accomplice run away, one after the other.'

b. * Der Wächter sah den Einbrecher und seinen Helfer einer nach
the watchman saw the burglar and his accomplice$_{acc}$ one$_{nom}$ after
dem anderen weglaufen.
the other run.away

- with raising verbs, nominativ adjunct phrases are ungrammatical
- the subjcet of the embedded predicate is identical to the object of the matrix verb
- both syntactic and semantic information is shared → both the object of the matrix verb and the subject of the embedded predicate are accusative
- similar data for Iclandic (Andrews, 1982) and Russian (Neidle, 1982)

Conclusion of the Data Section

- raising verbs (*Kim seems to sleep.*)
  - do not assign a semantic role to the subject of the embedded element
  - allow embedding of predicates with an expletive subject / without a subject
  - subject or object of the higher verb is identical to the subject of the embedded verb
- control verbs (*Kim tries to sleep.*)
  - assign a semantic role
  - do not embed predicates with expletive subject or with no subject
  - one argument is coreferent with the subject of the embedded verb

The Representation of Subjects (I)

- normaly the subject is not expressed in non-finite verbal projections:

(62) a. John tries to read the book.
b. * John tries to John read the book.
c. * John tries John to read the book.

→ subjects are represented separately (Borsley, 1987, 1989)

- a VP is a projection of a verbal head with all elements in SUBCAT saturated
- Definition of maximal projection: projection of a head that has an empty subcat list

Descriptions for Raising and Control Predicates

General Pattern for Raising Verbs:

$$\begin{bmatrix} \ldots\text{SUBJ} & \boxed{1} \\ \text{SUBCAT} & \left\langle \text{VP}[\text{SUBJ}\ \boxed{1}] \right\rangle \end{bmatrix}$$

The subject of the verb is identical to whatever the subject of the embedded verb is. The subject of the embedded verb may be linked to a semantic role of the embedded verb. (seem(sleep($\boxed{1}$)))

General Pattern for Subject Control Verbs:

$$\begin{bmatrix} \ldots\text{SUBJ} & \left\langle \text{NP}_{\boxed{1}} \right\rangle \\ \text{SUBCAT} & \left\langle \text{VP}[\text{SUBJ} \left\langle \text{NP}_{\boxed{1}} \right\rangle] \right\rangle \end{bmatrix}$$

The subject of the verb is coindexed with the subject of the embedded VP.

The subject fills a semantic role of the higher and the lower verb (try($\boxed{1}$,sleep($\boxed{1}$))).

Outline

- Why Syntax? / Phrase Structure Grammars
- The Formalism
- Valence and Grammar Rules
- Complementation
- Semantics
- Adjunction
- The Lexicon
- Constituent Order (Local Dependencies)
- Nonlocal Dependencies
- Raising and Control
- **Complex Predicates**

Complex Predicates

- verbs may embed other verbal projections

(63) a. Er liest es.
he reads it

b. weil er ihm es zu lesen verspricht.
because he him$_{dat}$ it$_{acc}$ to read promises
'because he promises him to read it.'

- evidence that certain verbs form a complex head with the verb they embed:
  - permutation of complements of both heads
  - embedded verbal element may not be moved (certain kinds of movement)
  - scope of adjuncts
- we will look at some of these, for details see (Bech, 1955)

Permutation of Complements of Different Heads

- although the elements between *weil* and the verbs depend on differnt heads, they may be permuted:

(64) weil es ihm jemand zu lesen versprochen hat. (Haider, 1990)
because it$_{acc}$ him$_{dat}$ somebody$_{nom}$ to read promised has
'because somebody promised him to read it.'

- *es* ('it') is the object of *lesen* ('read'), but it is not adjacent to its head.

Certain Verbs Have to Be Adjacent to Their Matrix Verb

Evidence for a Verbal Complex:

no scrambling of the VP:

(65) a. * daß [das Buch lesen] Karl wird.
that the book read Karl will
'that Karl will read the book.'

b. * das Buch, [das lesen] Karl wird
the book that read Karl will
'the book, that Karl will read'

Certain Verbs Cannot be Moved to the Right

(66) a. weil Karl das Buch zu lesen scheint.
because Karl the book to read seems
'because Karl seems to read the book.'

b. * weil Karl scheint das Buch zu lesen.
because Karl seems the book to read

(67) a. daß Karl das Buch zu lesen versucht.
that Karl the book to read tries
'that Karl tries to read the book.'

b. daß Karl versucht, das Buch zu lesen.
that Karl tries the book to read
'that Karl tries to read the book.'

c. daß Karl das Buch lesen wird.
that Karl the book read will
'that Karl will read the book.'

d. * daß Karl wird das Buch lesen.
that Karl will the book read

e. daß Karl das Buch gelesen hat.
that Karl the book red has
'that Karl red the book.'

f. * daß Karl hat das Buch gelesen.
that Karl has the book red

Reordering of Verbs

- the finite verb may appear betwen a verb and its complements:

(68) a. daß Karl das Buch lesen können *wird*. (read can will)
b. daß Karl das Buch *wird* lesen können. (will read can)

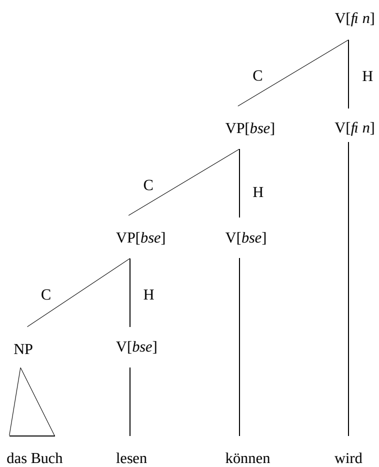
Coordination of Verbal Complexes

- If we have verbal complexes, we can explain (69) easily.

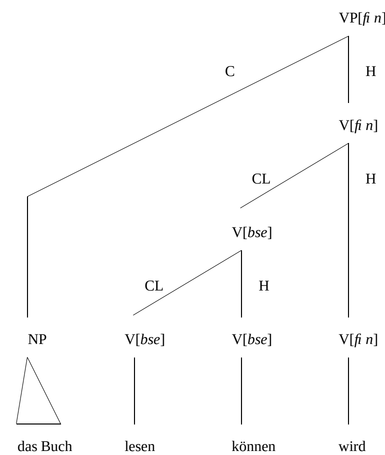
(69) Ich liebte ihn, und ich fühlte, daß er mich auch geliebt hat oder
I loved him and I felt that he me also loved has or
doch, daß er mich **hätte [[lieben wollen] oder [lieben**
at.least that he me had love want.to or love
müssen]]. (Hoberg, 1981)
must

- the two verbal complexes are coordinated and the governing verb (*hätte*) is positioned to the left
- Coordination data is weak evidence.

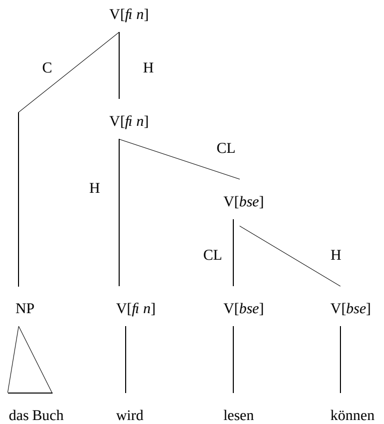
Uszkoreit (1987): The VP Analysis



Johnson (1986): Verbal Elements are Combined First



A Simple Solution for Reordering



Wird to the left of its verbal complement

The Representation of Subjects (II)

- in English grammars one has a rule S → NP, VP
- in HPSG grammars for German the subject of fi nite verbs is usually analyzed parallel to other dependents

  motivation: subjects can appear anywhere between the other dependents

  (70) weil ihr keiner das Buch gab.
  because her$_{dat}$ nobody$_{nom}$ the book$_{acc}$ gave
- non-fi nite verbs do not have their subject on the subcat list
  it is represented as the value of a separate list: the SUBJ list
- fi nite verbs have their subject on the subcat list
  see also (Borsley, 1989) for Welsh
- both lexical items for fi nite and non-fi nite verbs are related to a stem by a lexical rule
  the lexical rule that licences the fi nite verb inserts the subject into the subcat list
- there is no schema for German that combines a head with its subject → only the subject of fi nite verbs surfaces

SUBJ as Head Feature

we have to be able to access the subject at the level of VP since it gets a semantic role

(71) Er versucht, das Buch zu lesen.
he tries the book to read
'He tries to read the book.'

we make SUBJ a head feature →
it is present at VPs and we can assign a semantic role (Kiss, 1992)

Lexical Entries for Auxiliaries: Subject Raising

Hinrichs and Nakazawa (1994), Chung (1993), Rentier (1994), Kathol (1995), Müller (1997):

werden ('will' stem-entry, preliminary):

$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{SUBJ} & \boxed{1} \\ \textit{verb} & \end{bmatrix} \\ \text{VCOMP} & \left\langle \text{V[SUBJ } \boxed{1}\text{]} \right\rangle \\ \textit{cat} & \end{bmatrix}$$

- new valence feature VCOMP
- subject of the embedded verb and the subject of the auxiliary are identical (auxiliaries are raising verbs)
  - the auxiliary does not assign a role

    (72) Es wird regnen.
    it$_{expl}$ will rain
  - the auxiliary does not care whether there actually is a subject

    (73) Dem Studenten wird vor der Prüfung grauen.
    the student$_{dat}$ will before the exam dread
    'The student will dread the exam.'

Lexical Entries for Auxiliaries: Argument Attraction

werden ('will' stem-entry, preliminary):

[HEAD [SUBJ [1] , *verb*]
SUBCAT [2]
VCOMP ⟨ V[SUBJ [1], SUBCAT [2]] ⟩
cat]

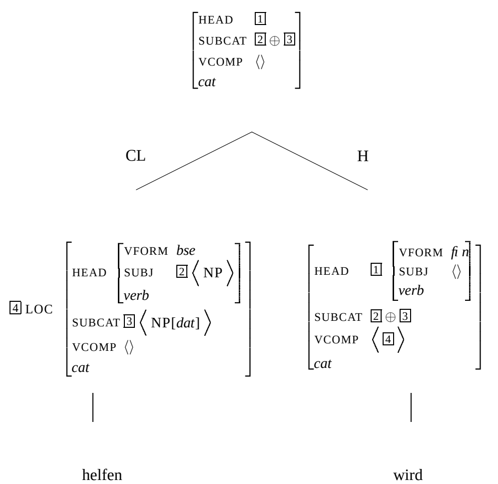
- complements of the embedded verb get complements of the auxiliary →
  auxiliary and verb are combined fi rst and then the dependent elements get saturated →
  we have a verbal complex
- the auxiliary takes the verb + its arguments

Schema 8 (Cluster Schema)

[SYNSEM|LOC|CAT|VCOMP [1]
HEAD-DTR [SYNSEM|LOC|CAT|VCOMP [1] ⊕ ⟨ [2] ⟩]
NON-HEAD-DTRS ⟨ [SYNSEM [2]] ⟩
head-cluster-structure]

- parallel to head complement structures, only the valence feature is different
- no elements from subcat of the head daughter get saturated

An Example: Analysis of the Verbal Complex



Auxiliaries: More Complex Complexes

- the lexical entries for other auxiliaries in German are parallel

future	*werden*
perfect	*haben* / *sein*

- forms may be combined

(74) daß er dem Mann geholfen haben wird.
that he the man helped have will

we have to ensure that verbal complexes that are embedded under a complex forming verb are complete as far as complex formation is concerned:

(75) * daß er dem Mann haben wird.
that he the man have will

werden ('will' stem-entry, preliminary):

[HEAD [SUBJ [1] , *verb*]
SUBCAT [2]
VCOMP ⟨ V[*bse*, SUBJ [1], SUBCAT [2], VCOMP ⟨⟩] ⟩
cat]

Avoiding Spurious Ambiguities

werden (‘will’ stem-entry, fi nal):

HEAD [SUBJ [1], *verb*]
SUBCAT [2]
VCOMP ⟨ V[LEX+ , *bse*, SUBJ [1], SUBCAT [2], VCOMP ⟨⟩] ⟩
cat

- selection of a LEX+ projection =
  quasi lexical elements (lexical entries and verbal complexes) $\rightarrow$
  structures in (76b–c) are excluded

(76) a. er seiner Tochter ein Märchen [erzählen wird].
he his daughter a fairytale tell wird
‘He will have to tell a fairytale to his daughter.’

b. er seiner Tochter [[ein Märchen erzählen] wird]].

c. er [[seiner Tochter ein Märchen erzählen] wird]].

Schema 9 (Cluster Schema)

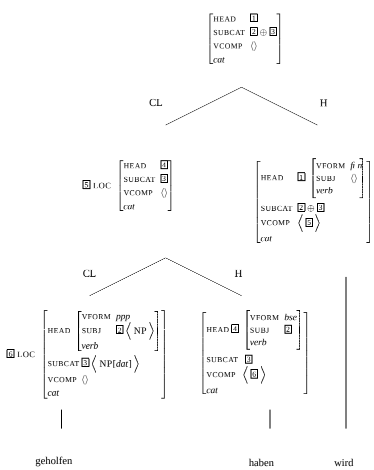
SYNSEM [LOC|CAT|VCOMP [1], LEX +]
HEAD-DTR [SYNSEM|LOC|CAT|VCOMP [1] $\oplus$ ⟨ [2] ⟩]
NON-HEAD-DTRS ⟨ [SYNSEM [2]] ⟩
head-cluster-structure

- schema can be applied recursively:

(77) daß er dem Mann [[geholfen haben] wird].
that he the man help have will
‘that he will have helped the man.’

- first the verbal complex *geholfen haben* is formed (LEX+)
  then it is embedded under *wird*

Analysis of the Verbal Complex



Verbal Complexes with Control Verbs

(78) weil es keiner [zu lesen versucht].
because it_{acc} nobody_{nom} to read tries
‘because nobody tries to read it.’

- the verbal complexes with control verbs are similar to those with raising verbs
- lexical entries differ in assigning a role to the subject of the embedded verb
- identifi cation of indices not of *synsem* objects
  versuchen (‘try’, non-fi nite version:

CAT [HEAD [SUBJ ⟨ $\text{NP}_{[1]}$ ⟩, *verb*], SUBCAT [2], VCOMP ⟨ V[*inf*, LEX+, SUBJ ⟨ $\text{NP}_{[1]}$ ⟩, SUBCAT [2]]:[3] ⟩]
CONT [AGENT [1], PROPOSITION [3], *versuchen*]
loc

- see Kiss (1995) for more

General Information about HPSG

- HPSG framework: http://hpsg.stanford.edu/
- Literature: http://www.dfki.de/lt/HPSG/
- systems
  - Development Systems
    - ⋆ ALE, CMU & Tübingen, Carpenter and Penn (1996); Penn and Carpenter (1999) http://www.sfs.nphil.uni-tuebingen.de/~gpenn/ale.html
    - ⋆ LKB, CSLI Stanford (Copestake, 1999) http://hpsg.stanford.edu
    - ⋆ PAGE, DFKI Saarbrücken (Uszkoreit et. al., 1994) http://www.dfki.de/pas/f2w.cgi?lts/page-e
    - ⋆ (Babel), DFKI Saarbrücken (Müller, 1996) http://www.dfki.de/~stefan/Babel/e_index.html
  - Runtime Systems
    - ⋆ LIGHT, DFKI Saarbrücken (Ciortuz, 2000)
    - ⋆ PET, DFKI Saarbrücken (Callmeier, In Press)
  - Others
    - ⋆ http://registry.dfki.de/

Applications

- General source of knowledge about language
  - extraction of subgrammars
  - extraction of CF-PSGs (Kiefer and Krieger, 2000)
  - explanation based learning (Neumann, 1997; Neumann and Flickinger, 1999)
- Speech/Translation
  - Verb*mobil* (Wahlster, 2000) http://verbmobil.dfki.de/
    - ⋆ German (Müller and Kasper, 2000)
    - ⋆ English (Flickinger, Copestake and Sag, 2000)
    - ⋆ Japanese (Siegel, 2000)
- Translation
  - German/Turkish (Kopru, 1999) using Babel
- Information Extraction
  - Whiteboard, DFKI Saarbrücken
- E-Mail Systems / Customer Interaction
  - YY: http://www.yy.com (English, Japanese, . . .)

Aims of the Course

- introduction to the basic ideas of Head-Driven Phrase Structure Grammar
- motivation of the feature geometry that is used in current publications enable you to read HPSG specific publications

Final Remarks

- You now have a construction set.
- Read! (http://www.dfki.de/lt/HPSG/)
- Write grammars for your language!
- Discuss consequences for analyses of other languages!
- Implement analyses!
- Ask! (Stefan.Mueller@dfki.de / HPSG Mailing List)
- Criticism: http://www.dfki.de/~stefan/
- Course web page: http://www.dfki.de/~stefan/Lehre/ESSLLI2001/

Feature Structures

- feature structure
- attribute-value matrix
- feature matrix
- Shieber (1986), Pollard and Sag (1987), Johnson (1988), Carpenter (1992), King (1994)

Def. 2 (Feature Structure—Preliminary Version)
*A feature structure is a set of pairs of the form [*ATTRIBUTE *value].*

ATTRIBUTE *is an element of the set of feature names ATTR.*

The component value *is*

- *atomic (a string)*
- *or again a feature structure.*

Feature Structures – Examples

$$\begin{bmatrix} \text{A1} & \textit{W1} \\ \text{A2} & \textit{W2} \\ \text{A3} & \textit{W3} \end{bmatrix}$$

$$\begin{bmatrix} \text{A1} & \textit{W1} \\ \text{A2} & \begin{bmatrix} \text{A21} & \textit{W21} \\ \text{A22} & \begin{bmatrix} \text{A221} & \textit{W221} \\ \text{A222} & \textit{W222} \end{bmatrix} \end{bmatrix} \\ \text{A3} & \textit{W3} \end{bmatrix}$$

the empty feature strucutre:

[ ]

Path

Def. 3 *A* **path** *in a feature structure is a continuous sequence of attributes in the feature structure. The* **value of a path** *is the feature structure at the end of the path.*

Structure Sharing

(79) a. Hans sleeps.
b. * Hans sleep.

Def. 4 *If two features in a feature structure have identical values, they are said to share a structure. This identity remains when the feature structure is used in operations. The value of the features is represented only once in the feature structure. The identity is marked by coindexation (little boxed numbers, e.g.* $\boxed{1}$*).*

other terms: coreference, reentrancy

Structure Sharing

A1 and A2 are token-identical:

$$\begin{bmatrix} \text{A1} & \boxed{1}\begin{bmatrix}\text{A3} & \mathit{W3}\end{bmatrix} \\ \text{A2} & \boxed{1} \end{bmatrix}$$

A1 and A2 are equal:

$$\begin{bmatrix} \text{A1} & \begin{bmatrix}\text{A3} & \mathit{W3}\end{bmatrix} \\ \text{A2} & \begin{bmatrix}\text{A3} & \mathit{W3}\end{bmatrix} \end{bmatrix}$$

difference for structure manipulations

Subject Verb Agreement and Structure Sharing

(80) a. Hans sleeps.
b. * Hans sleep.

$$\begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PHON} & \mathit{hans} \\ \text{AGR} & \boxed{1}\begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix} \end{bmatrix} \\ \text{PRED} & \begin{bmatrix} \text{PHON} & \mathit{sleeps} \\ \text{AGR} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Subsumption

Def. 5 *A feature structure F1* **subsumes** *a feature structure F2 (F1 $\succeq$ F2), iff:*

- *Every complete path in F1 is contained in F2 as a complete path and has the same value as in F1.*
- *Every pair of paths in F1 that is structure shared is also structure shared in F2.*

Examples

M1 $\succeq$ M2 $\succeq$ M7 $\succeq$ M8 $\succeq$ M9

M1 $\succeq$ M4 $\succeq$ M6 $\succeq$ M7 $\succeq$ M8 $\succeq$ M9

M1 $\succeq$ M3

M1 $\succeq$ M4 $\succeq$ M5

M1: [ ]

M2: $\begin{bmatrix}\text{CAT} & \mathit{np}\end{bmatrix}$ M3: $\begin{bmatrix}\text{CAT} & \mathit{vp}\end{bmatrix}$ M4: $\begin{bmatrix}\text{AGR}|\text{PER} & \mathit{3}\end{bmatrix}$

M5: $\begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{NUM} & \mathit{pl} \\ \text{PER} & \mathit{3}\end{bmatrix}\end{bmatrix}$ M6: $\begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix}\end{bmatrix}$

M7: $\begin{bmatrix}\text{CAT} & \mathit{np} \\ \text{AGR} & \begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix}\end{bmatrix}$ M8: $\begin{bmatrix}\text{CAT} & \mathit{np} \\ \text{AGR} & \begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix} \\ \text{SUBJ} & \begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix}\end{bmatrix}$ M9: $\begin{bmatrix}\text{CAT} & \mathit{np} \\ \text{AGR} & \boxed{1}\begin{bmatrix}\text{NUM} & \mathit{sg} \\ \text{PER} & \mathit{3}\end{bmatrix} \\ \text{SUBJ} & \boxed{1}\end{bmatrix}$

Unification

Def. 6 *Let F1, F2 and F3 be feature structures.*
F3 is the **unification** *of F1 and F2 (F3 = F1 ∧ F2), iff*

- *F1 and F2 subsume F3 and*
- *F3 subsumes all other feature structures that are also subsumed by F1 and F2*

Examples

$$\begin{bmatrix}\text{CAT} & np\end{bmatrix} \wedge \begin{bmatrix}\text{CAT} & np\end{bmatrix} = \begin{bmatrix}\text{CAT} & np\end{bmatrix}$$

$$\begin{bmatrix}\text{CAT} & np\end{bmatrix} \wedge \begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{PER} & 3\\ \text{NUM} & sg\end{bmatrix}\end{bmatrix} = \begin{bmatrix}\text{CAT} & np\\ \text{AGR} & \begin{bmatrix}\text{PER} & 3\\ \text{NUM} & sg\end{bmatrix}\end{bmatrix}$$

$$\begin{bmatrix}\text{CAT} & np\end{bmatrix} \wedge \begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{PER} & 3\\ \text{NUM} & sg\end{bmatrix}\end{bmatrix} \neq \begin{bmatrix}\text{CAT} & np\\ \text{AGR} & \begin{bmatrix}\text{PER} & 3\\ \text{NUM} & sg\end{bmatrix}\\ \text{SUBJ} & \begin{bmatrix}\text{NUM} & sg\end{bmatrix}\end{bmatrix}$$

Unification and Structure Sharing

$$\begin{bmatrix}\text{AGR} & \boxed{1}\begin{bmatrix}\text{NUM} & sg\end{bmatrix}\\ \text{SUBJ} & \boxed{1}\end{bmatrix} \wedge \begin{bmatrix}\text{SUBJ} & \begin{bmatrix}\text{PER} & 3\end{bmatrix}\end{bmatrix} = \begin{bmatrix}\text{AGR} & \boxed{1}\begin{bmatrix}\text{NUM} & sg\\ \text{PER} & 3\end{bmatrix}\\ \text{SUBJ} & \boxed{1}\end{bmatrix}$$

$$\begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{NUM} & sg\end{bmatrix}\\ \text{SUBJ} & \begin{bmatrix}\text{NUM} & sg\end{bmatrix}\end{bmatrix} \wedge \begin{bmatrix}\text{SUBJ} & \begin{bmatrix}\text{PER} & 3\end{bmatrix}\end{bmatrix} = \begin{bmatrix}\text{AGR} & \begin{bmatrix}\text{NUM} & sg\end{bmatrix}\\ \text{SUBJ} & \begin{bmatrix}\text{NUM} & sg\\ \text{PER} & 3\end{bmatrix}\end{bmatrix}$$

Lists

Lists of feature structures are introduced as a shorthand.

A list $\langle A_1, A_2, A_3 \rangle$ can be written as:

$$\begin{bmatrix}\text{FIRST} & A_1\\ \text{REST} & \begin{bmatrix}\text{FIRST} & A_2\\ \text{REST} & \begin{bmatrix}\text{FIRST} & A_3\\ \text{REST} & nil\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

$\langle\rangle$ stands for the empty list, i.e., a list with no elements

Functions and Relations

$$append(\left\langle X_1, X_2, \ldots, X_n \right\rangle, \left\langle Y_1, Y_2, \ldots, Y_m \right\rangle) = \left\langle X_1, X_2, \ldots, X_n, Y_1, Y_2, \ldots, Y_m \right\rangle$$

symbol for *append*: $\oplus$

A is the concatenation of the value of B with the value of C:

$$\begin{bmatrix} \text{A} & \boxed{1} \oplus \boxed{2} \\ \text{B} & \boxed{1} \\ \text{C} & \boxed{2} \end{bmatrix}$$

Typed Feature Structures

no restrictions on possible features and their values in a feature structure

$$\begin{bmatrix} \text{AGR} & \begin{bmatrix} \text{PER} & \mathit{3} \\ \text{NUM} & \mathit{sg} \end{bmatrix} \end{bmatrix}$$

$$\begin{bmatrix} \text{COLOR} & \mathit{blue} \end{bmatrix}$$

compatible, although totally different objects are described

negation and disjunction

$\neg[\text{NUM } \mathit{pl}] \stackrel{?}{=} [\text{NUM } \mathit{sg}] \vee [\text{NUM } \mathit{17}] \vee [\text{COLOR } \mathit{blue}]$

information unknown or irrelevant or inappropriate

Types and Appropriateness

What features belong to a structure of a given type?

What kind of values do they have?

Example:

$$\begin{bmatrix} \text{PHON} & \mathit{hans} \\ \text{AGR} & \begin{bmatrix} \text{PER} & \mathit{3} \\ \text{NUM} & \mathit{sg} \\ \mathit{agr} & \end{bmatrix} \\ \mathit{construction} & \end{bmatrix} \qquad \begin{bmatrix} \text{PHON} & \mathit{string} \\ \text{AGR} & \mathit{agr} \\ \mathit{construction} & \end{bmatrix} \qquad \begin{bmatrix} \text{PER} & \mathit{per} \\ \text{NUM} & \mathit{num} \\ \mathit{agr} & \end{bmatrix}$$

type definition: feature structures of the type *constr* always have the features PHON and AGR

feature structures of the type *agr* always have the features PER and NUM

complex types:

$$\begin{bmatrix} \text{PHON} & \mathit{string} \\ \text{AGR} & \begin{bmatrix} \text{PER} & \mathit{3} \\ \text{NUM} & \mathit{sg} \\ \mathit{agr} & \end{bmatrix} \\ \mathit{3rd\text{-}sg\text{-}construction} & \end{bmatrix}$$

Typed Feature Structures

$$\begin{bmatrix} \text{SUBJ} & \begin{bmatrix} \text{PHON} & \begin{bmatrix} \mathit{hans} \end{bmatrix} \\ \text{AGR} & \boxed{1} \begin{bmatrix} \text{NUM} & \begin{bmatrix} \mathit{sg} \end{bmatrix} \\ \text{PER} & \begin{bmatrix} \mathit{3} \end{bmatrix} \\ \mathit{agr} & \end{bmatrix} \\ \mathit{constr} & \end{bmatrix} \\ \text{PRED} & \begin{bmatrix} \text{PHON} & \begin{bmatrix} \mathit{sleeps} \end{bmatrix} \\ \text{AGR} & \boxed{1} \\ \mathit{constr} & \end{bmatrix} \\ \mathit{sentence} & \end{bmatrix}$$

Subsumption and Unification with Types

definition analogous to definition for untyped feature structures

Def. 7 *A type t1* **subsumes** *a type t2 (t1 $\succeq$ t2) iff*

- *If t1 and t2 do not have structure then t1 must be at least as specific as t2.*
- *If t1 and t2 have structure then t1 must be at least as specific as t2 and Every feature* ATTR *in feature structures of type t1 must be present in feature strucutres of type t2 and for the types $t1_{ATTR}$ and $t2_{ATTR}$ that belong to* ATTR *the following holds: $t1_{ATTR} \succeq t2_{ATTR}$.*

t1 is a **supertype** of *t2* and *t2* is a **subtype** of *t1*.

Def. 8 *Let t1, t2 and t3 be types. t3 is the* **unification** *of t1 and t2, iff*

- *t1 and t2 subsume t3 and*
- *t3 subsumes all types t that are also subsumed by t1 and t2*

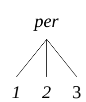
An Example

$$A = \begin{bmatrix} \text{A1} & a \\ \text{A2} & \begin{bmatrix} \text{A21} & c \\ & b \end{bmatrix} \\ & aa \end{bmatrix} \qquad B = \begin{bmatrix} \text{A1} & a \\ \text{A2} & \begin{bmatrix} \text{A21} & c \\ & d \end{bmatrix} \\ \text{A3} & e \\ & bb \end{bmatrix}$$

A $\succeq$ B, if aa $\succeq$ bb and b $\succeq$ d

Atomic and Complex Types in Inheritance Hierarchies

atomic:



similar hierarchies with complex types

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