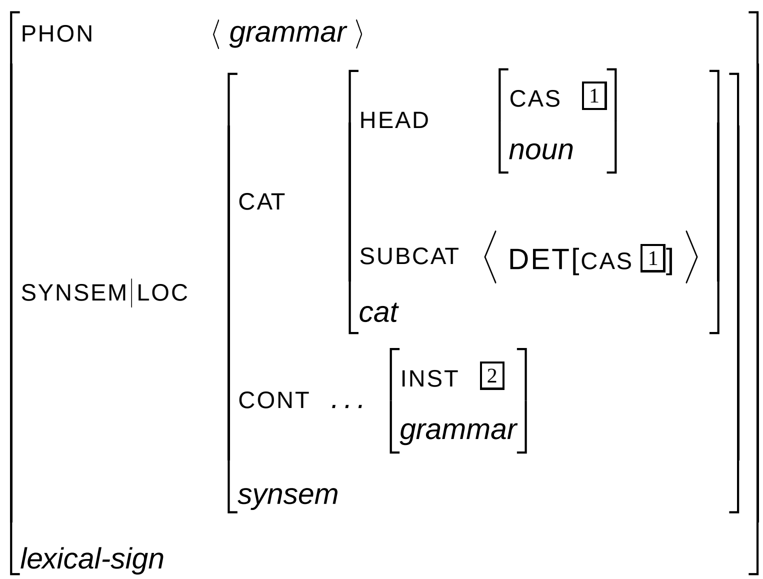
HPSG Background

Head-Driven Phrase Structure Grammar

- developed in the mid 1980s as an alternative to Transformational Grammar
- Pollard and Sag (1987, 1994)
- many contributions since then
  - syntactic theory
  - language typology
  - computational linguistics, grammar development
- annual HPSG conferences (since 1994):
  proceedings at CSLI online publications
- Websites:
  http://hpsg.stanford.edu/ and http://www.dfki.de/lt/HPSG/ (Literature)
- recent textbooks:
  (Sag and Wasow, 1999)

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:

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

Example

A feature structure that describes a human being:

$$\begin{bmatrix} \textsc{first-name} & \textit{max} \\ \textsc{last-name} & \textit{meier} \\ \textsc{birthday} & \textit{10.10.1985} \end{bmatrix}$$

recursive structures:

$$\begin{bmatrix} \textsc{first-name} & \textit{max} \\ \textsc{last-name} & \textit{meier} \\ \textsc{birthday} & \textit{10.10.1985} \\ \textsc{father} & \begin{bmatrix} \textsc{first-name} & \textit{peter} \\ \textsc{last-name} & \textit{meier} \\ \textsc{birthday} & \textit{10.05.1960} \\ \textsc{father} & \ldots \\ \textsc{mother} & \ldots \end{bmatrix} \\ \textsc{mother} & \ldots \end{bmatrix}$$

Exercise: How do we represent the daughters or sons of a human being?

Solution I

FIRST-NAME	*max*
LAST-NAME	*meier*
BIRTHDAY	*10.10.1985*
FATHER	...
MOTHER	...
DAUGHTER	...

What about persons with several daughters?

FIRST-NAME	*max*
LAST-NAME	*meier*
BIRTHDAY	*10.10.1985*
FATHER	...
MOTHER	...
DAUGHTER-1	...
DAUGHTER-2	...
DAUGHTER-3	...

How many features do we want? Where is the limit?

Solution II – Lists

FIRST-NAME	*max*
LAST-NAME	*meier*
BIRTHDAY	*10.10.1985*
FATHER	...
MOTHER	...
DAUGHTER	⟨ ..., ... ⟩

What about sons?

Do we want to differentiate? Yes, but it is a property of the described objects:

FIRST-NAME	*max*
LAST-NAME	*meier*
BIRTHDAY	*10.10.1985*
SEX	*male*
FATHER	...
MOTHER	...
CHILDREN	⟨ ..., ... ⟩

Lists

Lists of feature structures are introduced as a shorthand.

A list $\left\langle \mathrm{A}_1, \mathrm{A}_2, \mathrm{A}_3 \right\rangle$ can be written as:

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

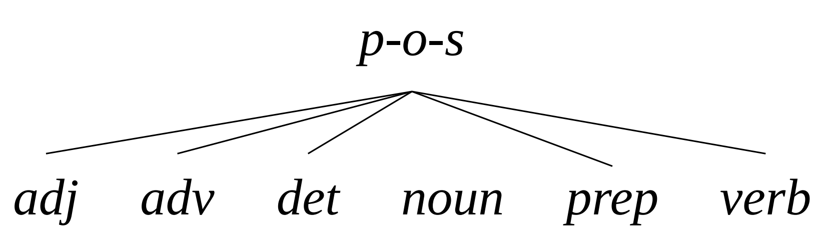
$\langle\rangle$ stands for the empty list, i.e., a list with no elements

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 $\boxed{1}$]

Structure Sharing

A1 and A2 are token-identical:

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

A1 and A2 are equal:

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

difference for structure manipulations

Subject Verb Agreement and Structure Sharing

(17) a. Hans sleeps.

b. * Hans sleep.

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

Unification

Def. 6 *Let F1, F2 and F3 be feature structures.*
F3 is the **unification** *of F1 and F2 (F3 = F1 $\wedge$ 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

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

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

Valence and Grammar Rules: HPSG

- complements are specified as complex categories in the lexical representation of the head
- like Categorial Grammar
- verb subcat

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

Representation of Valence in Feature Descriptions

- a lexical entry consists of:

  gibt ('gives' finite form):

$$\begin{bmatrix} \text{PHON} & \langle \textit{gibt} \rangle \\ \text{PART-OF-SPEECH} & \textit{verb} \\ \text{SUBCAT} & \left\langle \text{NP}[\textit{nom}], \text{NP}[\textit{acc}], \text{NP}[\textit{dat}] \right\rangle \end{bmatrix}$$

  - phonological information
  - information about part of speech
  - valence information: a list of feature descriptions

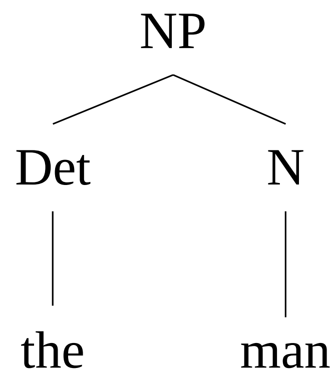
- NP[*nom*] is an abbreviation for a feature description

Representation of Grammar Rules (I)

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

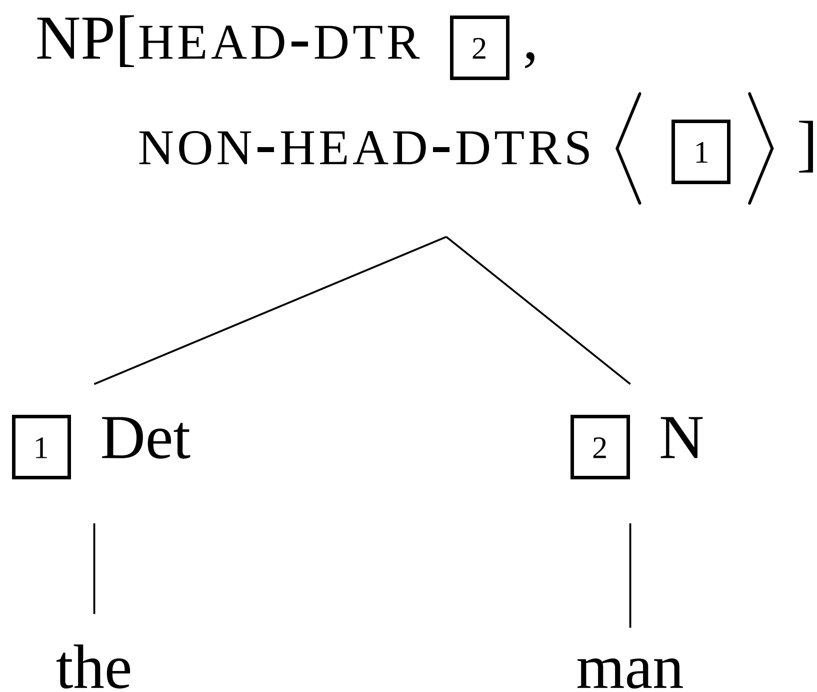
  everything is modeled in feature structures
- distinction between immediate dominance and linear precedence
- dominance is encoded in the daughter features of a structure (heads, non-heads)
- precedence is contained implicitly in the PHON value of a sign

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



$$\begin{bmatrix} \textsc{phon} & \langle \textit{the man} \rangle \\ \textsc{head-dtr} & \begin{bmatrix} \textsc{phon}\ \langle \textit{man} \rangle \end{bmatrix} \\ \textsc{non-head-dtrs} & \left\langle \begin{bmatrix} \textsc{phon}\ \langle \textit{the} \rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Tree with DTRS Values (I)



Representation of Grammar Rules (II)

- dominance rule:

Schema 1 (Head Complement Schema (binary branching))

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

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

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

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

- possible instantiation:

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

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

Functions and Relations

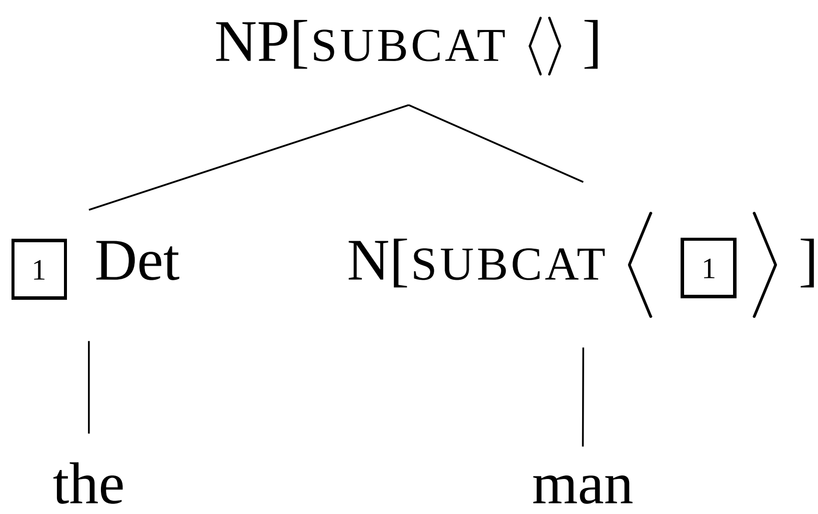
$$append(\left\langle X_1, X_2, \ldots, X_n \right\rangle, \left\langle Y_1, Y_2, \ldots, Y_m \right\rangle) = \left\langle X_1, X_2, \ldots, X_n, Y_1, Y_2, \ldots, Y_m \right\rangle$$

symbol for *append*: $\oplus$

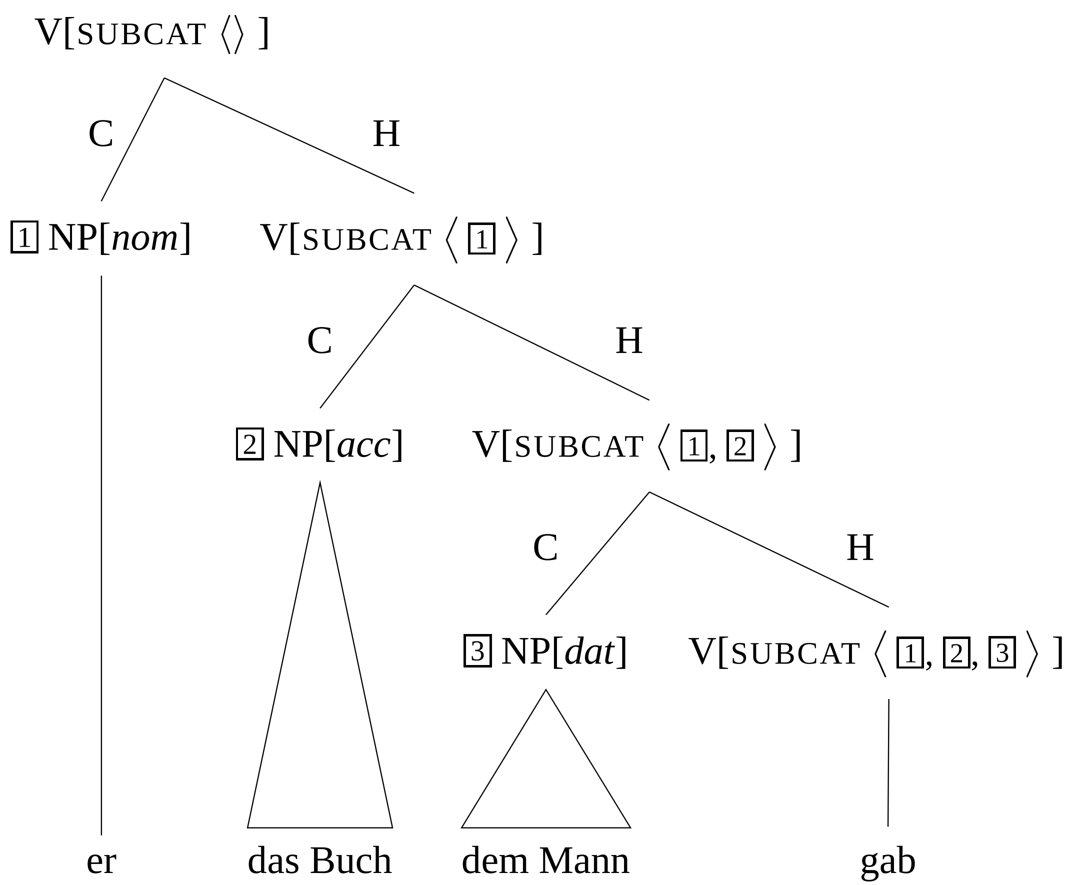
A is the concatenation of the value of B with the value of C:

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

An Example



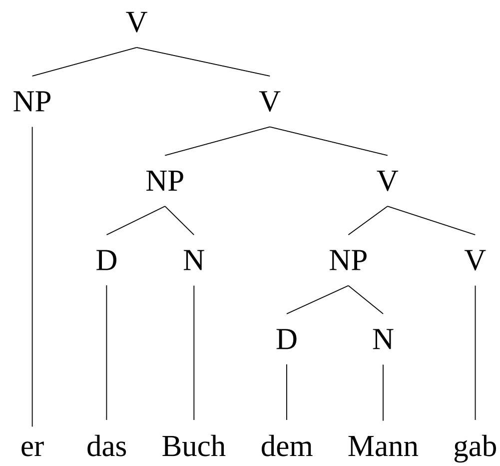
A More Complex Example



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

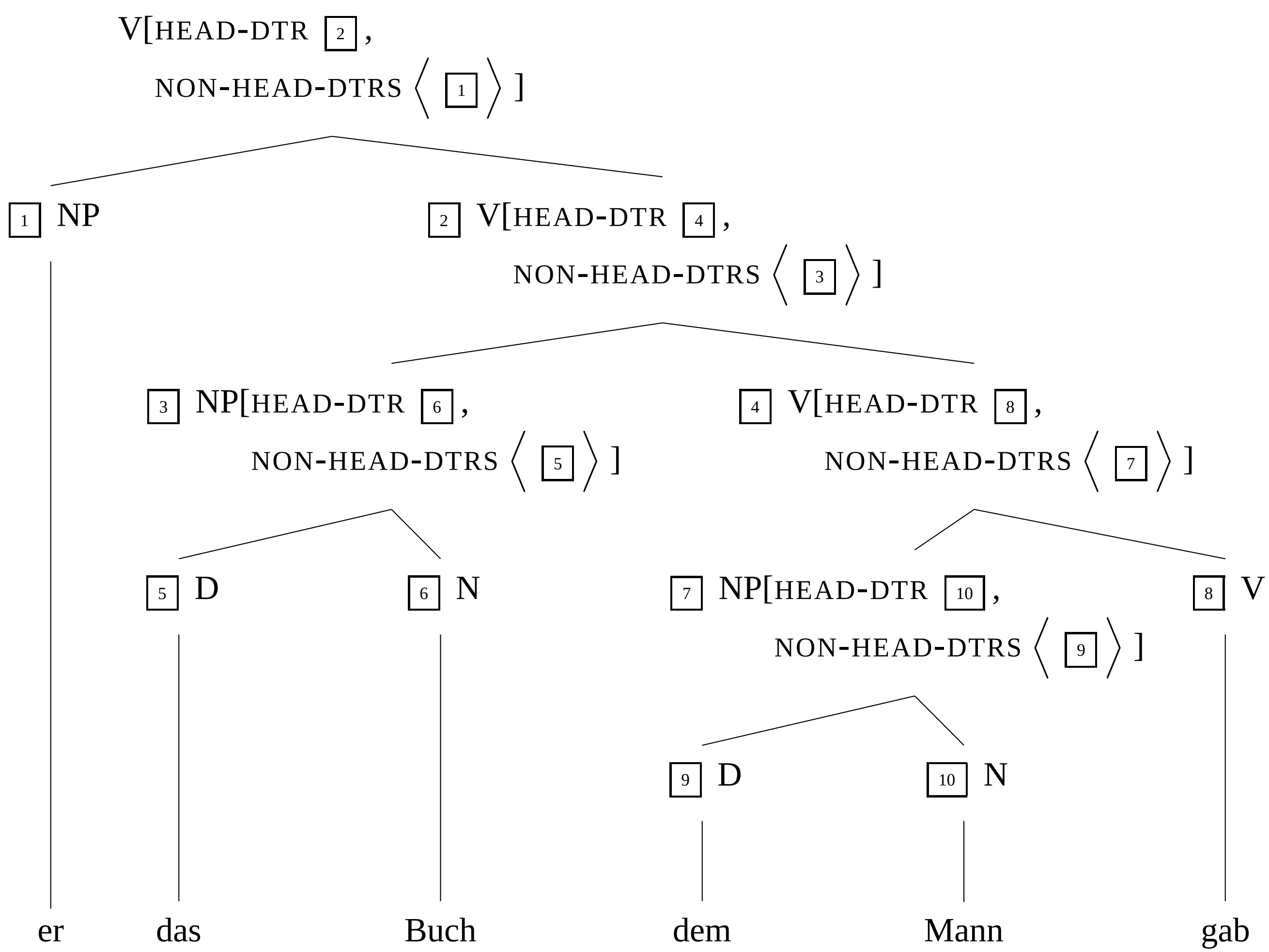
H = Head, C = Complement (= Non-Head)

Representation with Feature Structure – PHON Values (II)



$$\begin{bmatrix} \textsc{phon} & \langle \textit{dem Mann gab} \rangle \\ \textsc{head-dtr} & \begin{bmatrix} \textsc{phon} \ \langle \textit{gab} \rangle \end{bmatrix} \\ \textsc{non-head-dtrs} & \left\langle \begin{bmatrix} \textsc{phon} & \langle \textit{dem Mann} \rangle \\ \textsc{head-dtr} & \begin{bmatrix} \textsc{phon} \ \langle \textit{Mann} \rangle \end{bmatrix} \\ \textsc{non-head-dtrs} & \left\langle \begin{bmatrix} \textsc{phon} \ \langle \textit{dem} \rangle \end{bmatrix} \right\rangle \end{bmatrix} \right\rangle \end{bmatrix}$$

Tree with DTRS Values (II)



Representation with Feature Structure – PHON values (III)

$$
\begin{bmatrix}
\text{PHON} & \langle \textit{er das Buch dem Mann gab} \rangle \\
\text{HEAD-DTR} & \begin{bmatrix}
\text{PHON} & \langle \textit{das Buch dem Mann gab} \rangle \\
\text{HEAD-DTR} & \begin{bmatrix}
\text{PHON} & \langle \textit{dem Mann gab} \rangle \\
\text{HEAD-DTR} & \begin{bmatrix} \text{PHON} & \langle \textit{gab} \rangle \end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix}
\text{PHON} & \langle \textit{dem Mann} \rangle \\
\text{HEAD-DTR} & \begin{bmatrix} \text{PHON} & \langle \textit{Mann} \rangle \end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix} \text{PHON} & \langle \textit{dem} \rangle \end{bmatrix} \right\rangle
\end{bmatrix} \right\rangle
\end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix}
\text{PHON} & \langle \textit{das Buch} \rangle \\
\text{HEAD-DTR} & \begin{bmatrix} \text{PHON} & \langle \textit{Buch} \rangle \end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix} \text{PHON} & \langle \textit{das} \rangle \end{bmatrix} \right\rangle
\end{bmatrix} \right\rangle
\end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \begin{bmatrix} \text{PHON} & \langle \textit{er} \rangle \end{bmatrix} \right\rangle
\end{bmatrix}
$$

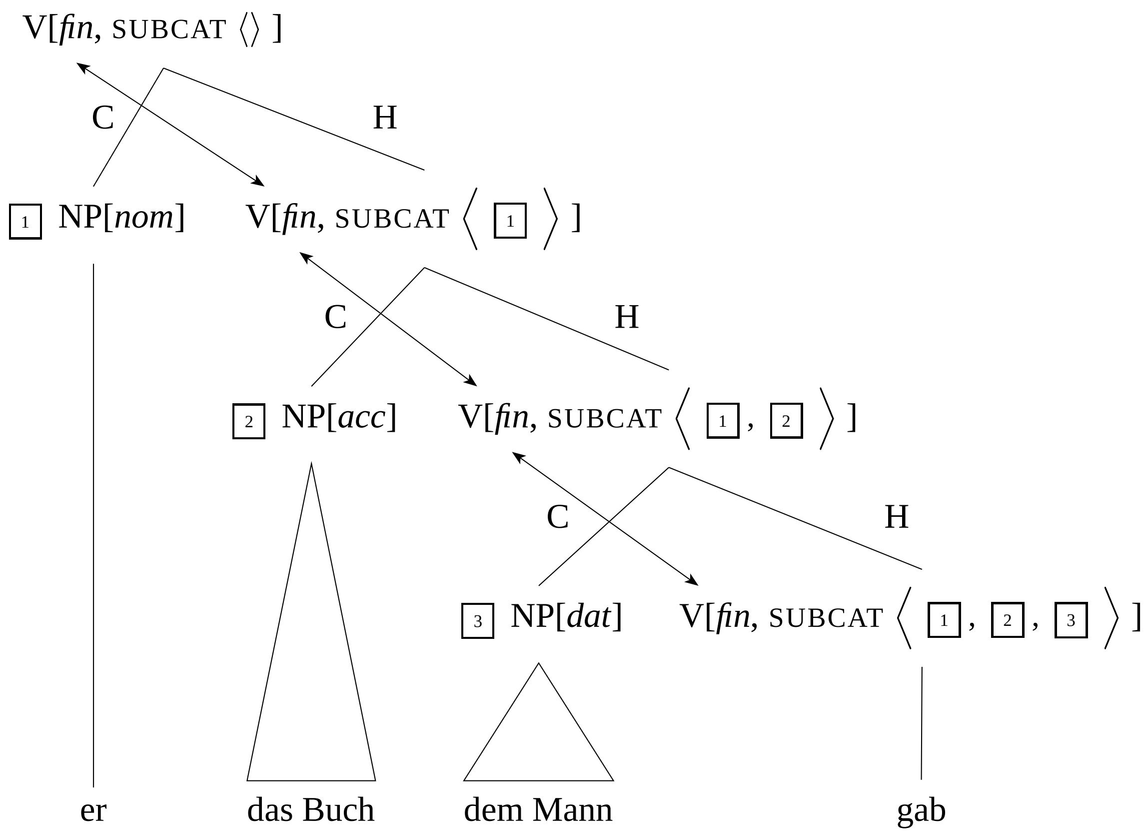
Representation in Feature Structures (Part)

$$\begin{bmatrix}
\text{PHON } \langle \textit{dem Mann, gab} \rangle \\
\text{SUBCAT } \boxed{1} \\
\text{HEAD-DTR } \begin{bmatrix} \text{PHON } \langle \textit{gab} \rangle \\ \text{SUBCAT } \boxed{1} \left\langle \text{NP}[\textit{nom}], \text{NP}[\textit{acc}] \right\rangle \oplus \left\langle \boxed{2} \right\rangle \end{bmatrix} \\
\text{NON-HEAD-DTRS } \left\langle \boxed{2} \begin{bmatrix} \text{PHON } \langle \textit{dem Mann} \rangle \\ \text{P-O-S } \textit{noun} \\ \text{SUBCAT } \langle\rangle \\ \text{HEAD-DTR } \ldots \\ \text{NON-HEAD-DTRS } \ldots \\ \textit{head-complement-structure} \end{bmatrix} \right\rangle \\
\textit{head-complement-structure}
\end{bmatrix}$$

Representation in Feature Structures (Part)

$$
\begin{bmatrix}
\text{PHON}\ \langle\ \textit{er, das Buch, dem Mann, gab}\ \rangle \\
\text{SUBCAT}\ \boxed{1} \\
\text{HEAD-DTR}\ \begin{bmatrix}
\text{PHON}\ \langle\ \textit{das Buch, dem Mann, gab}\ \rangle \\
\text{SUBCAT}\ \boxed{1}\ \langle\rangle \oplus \left\langle\ \boxed{2}\ \right\rangle \\
\textit{head-complement-structure}
\end{bmatrix} \\
\text{NON-HEAD-DTRS}\ \left\langle\ \boxed{2}\ \begin{bmatrix}
\text{PHON}\ \langle\ \textit{er}\ \rangle \\
\text{P-O-S}\ \textit{noun} \\
\text{SUBCAT}\ \langle\rangle \\
\text{HEAD-DTR}\ \ldots \\
\text{NON-HEAD-DTRS}\ \ldots \\
\textit{head-complement-structure}
\end{bmatrix}\ \right\rangle \\
\textit{head-complement-structure}
\end{bmatrix}
$$

Projection of Head Properties



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

Representation in Feature Descriptions: the HEAD Value

- possible feature geometry:

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes} \\ \text{P-O-S} & \textit{p-o-s} \\ \text{VFORM} & \textit{vform} \\ \text{SUBCAT} & \textit{list} \end{bmatrix}$$

- more structure, grouping information together for projection:

$$\begin{bmatrix} \text{PHON} & \textit{list of phonemes} \\ \text{HEAD} & \begin{bmatrix} \text{P-O-S} & \textit{p-o-s} \\ \text{VFORM} & \textit{vform} \end{bmatrix} \\ \text{SUBCAT} & \textit{list} \end{bmatrix}$$

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 filled in

  for nouns *vform* is not filled 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):

  $$\left[\phantom{\rule{8cm}{3cm}} \right]$$

A Lexical Entry with Head Features

- a lexical entry consists of:

  gibt ('gives' finite form):

  $$\begin{bmatrix} \text{PHON} & \langle \textit{gibt} \rangle \\ & \\ & \\ & \end{bmatrix}$$

  – phonological information

A Lexical Entry with Head Features

- a lexical entry consists of:

  gibt (‘gives’ finite form):

$$\begin{bmatrix} \text{PHON} & \langle \textit{gibt} \rangle \\ \text{HEAD} & \begin{bmatrix} \text{VFORM} & \textit{fin} \\ \textit{verb} & \end{bmatrix} \end{bmatrix}$$

  - phonological information
  - head information (part of speech, finiteness, . . .)

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, finiteness, . . .)
  - valence information: a list of feature descriptions

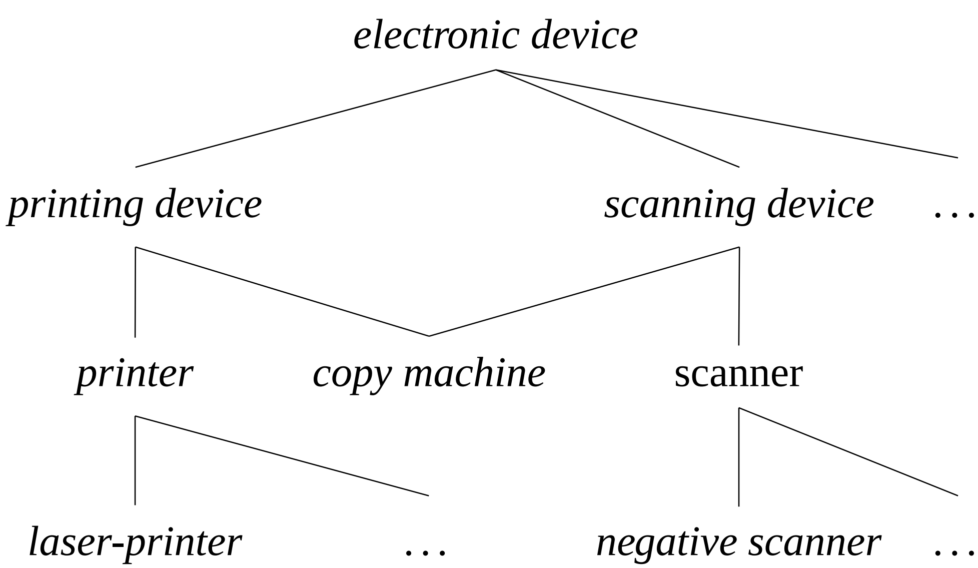
Head Feature Principle (HFP)

- 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 (1994) 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

Head Complement Schema + Head Feature Principle

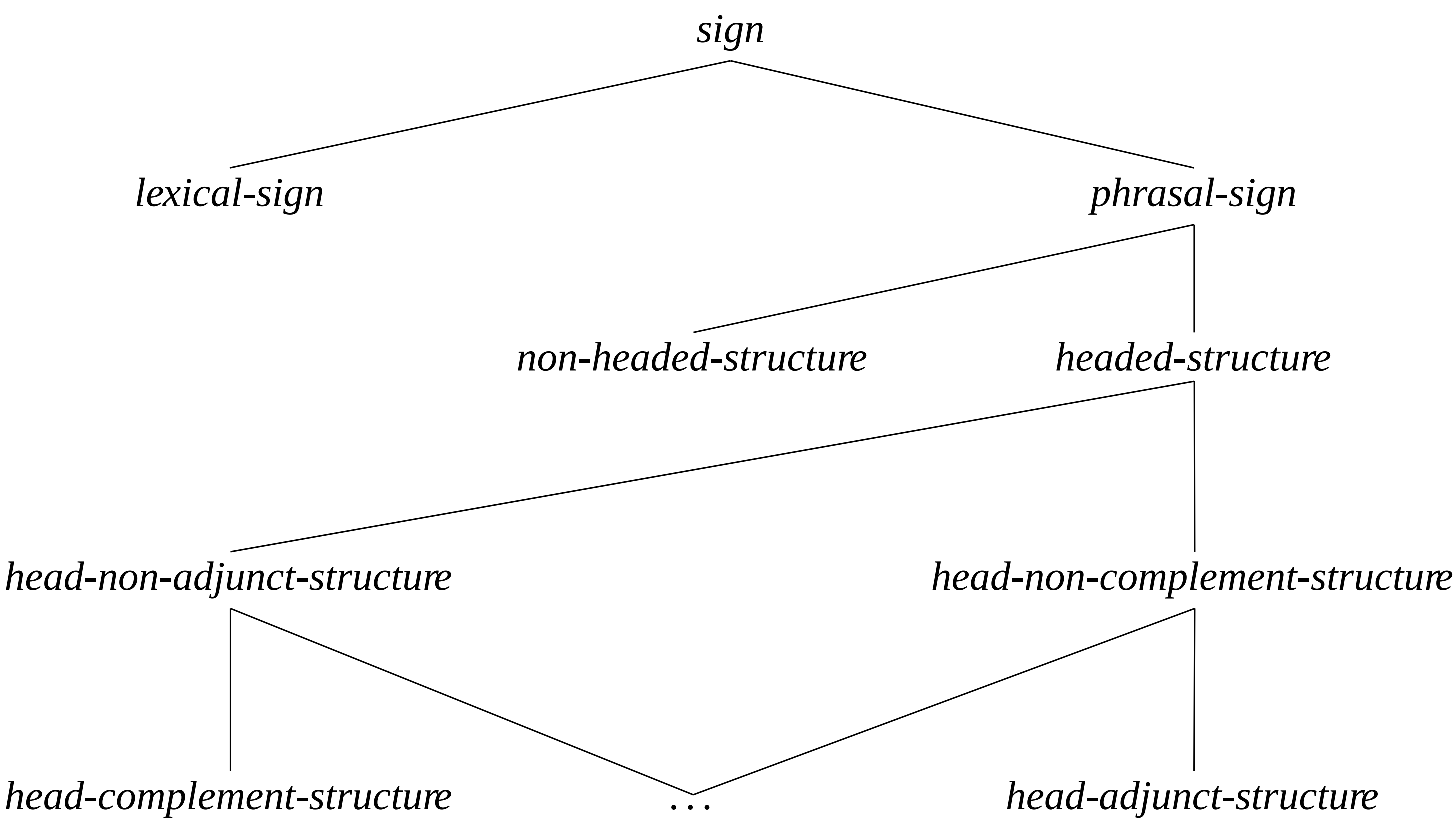
$$\begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{SUBCAT} & \boxed{2} \\ \text{HEAD-DTR} & \begin{bmatrix} \text{HEAD} & \boxed{1} \\ \text{SUBCAT} & \boxed{2} \oplus \left\langle \boxed{3} \right\rangle \end{bmatrix} \\ \text{NON-HEAD-DTRS} & \left\langle \boxed{3} \right\rangle \\ \textit{head-complement-structure}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

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

Head Complement Structure with Head Information Shared

$$
\begin{bmatrix}
\text{PHON} & \langle \textit{dem Mann, gab} \rangle \\
\text{HEAD} & \boxed{1} \\
\text{SUBCAT} & \boxed{2} \\
\text{HEAD-DTR} & \begin{bmatrix} \text{PHON} & \langle \textit{gab} \rangle \\ \text{HEAD} & \boxed{1} \begin{bmatrix} \text{VFORM} & \textit{fin} \\ \textit{verb} & \end{bmatrix} \\ \text{SUBCAT} & \boxed{2} \left\langle \text{NP}[\textit{nom}], \text{NP}[\textit{acc}] \right\rangle \oplus \left\langle \boxed{3} \right\rangle \\ \textit{lexical-sign} & \end{bmatrix} \\
\text{NON-HEAD-DTRS} & \left\langle \boxed{3} \begin{bmatrix} \text{PHON} & \langle \textit{dem Mann} \rangle \\ \text{HEAD} & \begin{bmatrix} \text{CAS} & \textit{dat} \\ \textit{noun} & \end{bmatrix} \\ \text{SUBCAT} & \langle\rangle \\ \text{HEAD-DTR} & \ldots \\ \text{NON-HEAD-DTRS} & \ldots \\ \textit{head-complement-structure} & \end{bmatrix} \right\rangle \\
\textit{head-complement-structure} &
\end{bmatrix}
$$

Type Hierarchy for *sign*

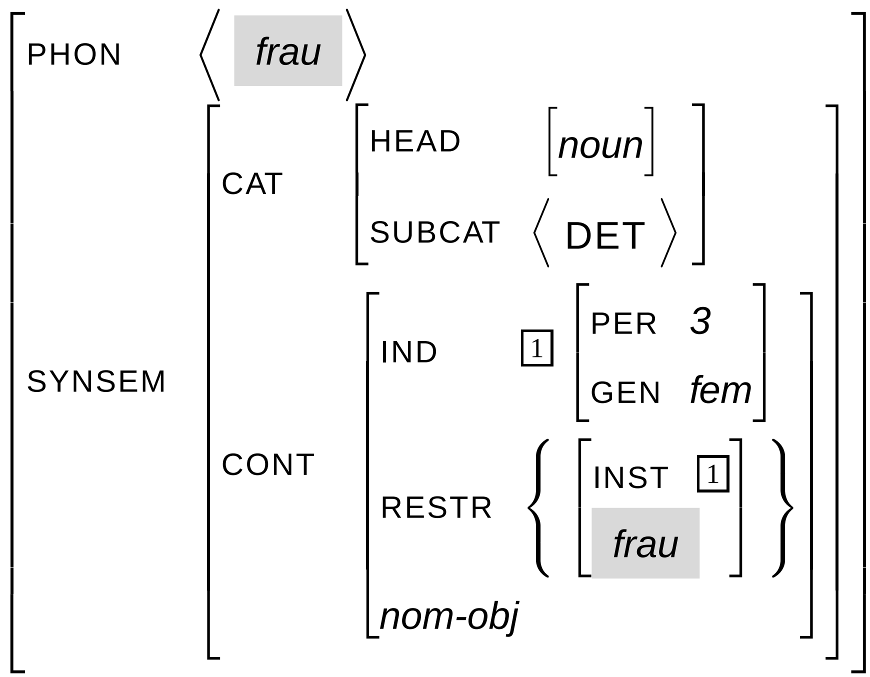


The Lexicon

- 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’):



just very few information is idiosyncratic

Factoring Out Common Information

a. all nouns

$$\left[\textsc{synsem}\ \left[\begin{array}{l}\textsc{cat}|\textsc{head}\ \left[\textit{noun}\right]\\ \textsc{cont}\ \textit{nom-obj}\end{array}\right]\right]$$

Factoring Out Common Information

a. all nouns

$$\left[\text{SYNSEM}\ \left[\begin{array}{l}\text{CAT}|\text{HEAD}\ \left[\textit{noun}\right]\\ \text{CONT}\ \textit{nom-obj}\end{array}\right]\right]$$

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

$$\left[\text{SYNSEM}\ \left[\begin{array}{ll}\text{CAT} & \left[\text{SUBCAT}\ \left\langle \text{DET} \right\rangle\right]\\ \text{CONT} & \left[\begin{array}{ll}\text{IND} & \boxed{1}\left[\text{PER}\ \textit{3}\right]\\ \text{RESTR} & \left\{\left[\begin{array}{l}\text{INST}\ \boxed{1}\\ \textit{psoa}\end{array}\right], \ldots\right\}\end{array}\right]\end{array}\right]\right]$$

Factoring Out Common Information

a. all nouns

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT}|\text{HEAD} & \begin{bmatrix} \textit{noun} \end{bmatrix} \\ \text{CONT} & \textit{nom-obj} \end{bmatrix} \end{bmatrix}$$

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

$$\begin{bmatrix} \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{SUBCAT} & \left\langle \text{DET} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{IND} & \boxed{1} \begin{bmatrix} \text{PER} & \textit{3} \end{bmatrix} \\ \text{RESTR} & \left\{ \begin{bmatrix} \text{INST} & \boxed{1} \\ \textit{psoa} & \end{bmatrix}, \ldots \right\} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

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

$$\begin{bmatrix} \text{SYNSEM}|\text{CONT}|\text{IND}|\text{GEN} & \textit{fem} \end{bmatrix}$$

Factoring Out Common Information

a lexical entry for a verb with dative complement:

helf- ('help', lexical entry (root)):

$$\begin{bmatrix} \text{PHON} & \langle \textit{helf} \rangle \\ \text{SYNSEM} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \text{SUBJ} & \langle \text{NP}[\textit{nom}]_{\boxed{1}} \rangle \\ \textit{verb} & \end{bmatrix} \\ \text{SUBCAT} & \langle \text{NP}[\textit{dat}]_{\boxed{2}} \rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{AGENT} & \boxed{1} \\ \text{EXPERIENCER} & \boxed{2} \\ \textit{help} & \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

a. all verbs

$$\left[\text{SYNSEM}\ \left[\begin{array}{ll}\text{CAT}|\text{HEAD} & \left[\textit{verb}\right] \\ \text{CONT} & \left[\textit{psoa}\right]\end{array}\right]\right]$$

a. all verbs

$$\left[\text{SYNSEM} \left[\begin{array}{ll} \text{CAT}|\text{HEAD} & \left[\textit{verb}\right] \\ \text{CONT} & \left[\textit{psoa}\right] \end{array}\right]\right]$$

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

$$\left[\text{SYNSEM} \left[\text{CAT} \left[\begin{array}{ll} \text{HEAD}|\text{SUBJ} & \left\langle \text{NP}[\textit{nom}] \right\rangle \\ \text{SUBCAT} & \left\langle \text{NP}[\textit{dat}] \right\rangle \end{array}\right]\right]\right]$$

a. all verbs

$$\left[\text{SYNSEM}\ \left[\begin{array}{ll}\text{CAT}|\text{HEAD} & \left[\textit{verb}\right]\\ \text{CONT} & \left[\textit{psoa}\right]\end{array}\right]\right]$$

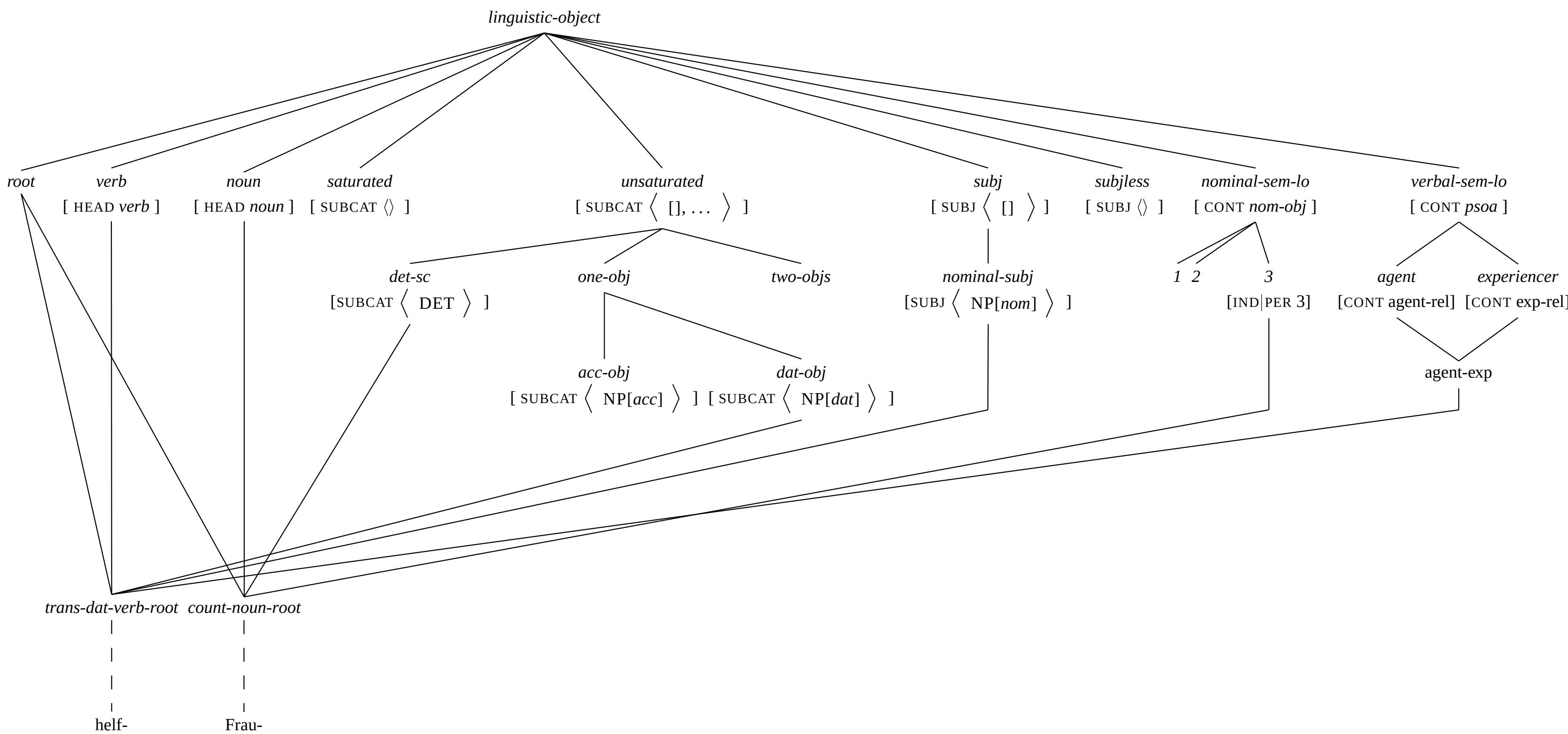
b. transitive verbs with a dative object (in addition to a)

$$\left[\text{SYNSEM}\ \left[\text{CAT}\ \left[\begin{array}{ll}\text{HEAD}|\text{SUBJ} & \left\langle \text{NP}[\textit{nom}] \right\rangle\\ \text{SUBCAT} & \left\langle \text{NP}[\textit{dat}] \right\rangle\end{array}\right]\right]\right]$$

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

$$\left[\text{SYNSEM}\ \left[\begin{array}{ll}\text{CAT} & \left[\begin{array}{ll}\text{HEAD}|\text{SUBJ} & \left\langle \left[\text{CONT}|\text{IND}\ \boxed{1}\right] \right\rangle\\ \text{SUBCAT} & \left\langle \left[\text{CONT}|\text{IND}\ \boxed{2}\right] \right\rangle\end{array}\right]\\ \text{CONT} & \left[\begin{array}{ll}\text{AGENT} & \boxed{1}\\ \text{EXPERIENCER} & \boxed{2}\\ \textit{agent-exp} & \end{array}\right]\end{array}\right]\right]$$

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

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

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

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 (1982), 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.

Lexical Rule for Passive

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

(15) a. The man kicks the dog.

b. The dog is kicked.

Lexical Rule for Passive with Morphology

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

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

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)

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, . . .)

References

Ackerman, Farrell and Webelhuth, Gert. 1998. *A Theory of Predicates*. CSLI Lecture Notes, No. 76, Stanford, California: CSLI Publications.

Barwise, Jon and Perry, John. 1983.

Borsley, Robert D. 1999. *Syntactic Theory: A Unified Approach*. London: Edward Arnold, second edition.

Bresnan, Joan. 1982. The Passive in Lexical Theory. In Joan Bresnan (ed.), *The Mental Representation of Grammatical Relations*, MIT Press Series on Cognitive Theory and Mental Representation, pages 3–86, Cambridge: Massachusetts, London: England: The MIT Press.

Callmeier, Ulrich. In Press. PET—A Platform for Experimentation with Efficient HPSG Processing Techniques. *Journal of Natural Language Engineering* 1(6), 99–108, (Special Issue on Efficient Processing with HPSG: Methods, Systems, Evaluation).

Carpenter, Bob. 1992. *The Logic of Typed Feature Structures*. Tracts in Theoretical Computer Science, Cambridge: Cambridge University Press.

Carpenter, Bob and Penn, Gerald. 1996. Efficient Parsing of Compiled Typed Attribute Value Logic Grammars. In Harry Bunt and Masaru Tomita (eds.), *Recent Advances in Parsing Technology*, Text, Speech and Language Technology, No. 1, Dordrecht/Boston/London: Kluwer Academic Publishers.

Ciortuz, Liviu-Virgil. 2000. Scaling Up the Abstract Machine for Unification of OSF-terms to do Head-Corner Parsing with Large-Scale Typed Unification Grammars. In Hinrichs et. al. (2000), pages 57–80.

Cooper, Robin, Mukai, Kuniaki and Perry, John (eds.). 1990. *Situation Theory And Its Applications, Volume 1*. CSLI Lecture Notes, No. 22, Stanford: Center for the Study of Language and Information.

Copestake, Ann. 1999. The (New) LKB System, ftp://www-csli.stanford.edu/~aac/newdoc.pdf. 06.24.99.

Copestake, Ann and Briscoe, Ted. 1992. Lexical Rules in a Unification Based Framework. In James Pustejovsky and Sabine Bergler (eds.), *Lexical Semantics and Knowledge Representation*, Lecture Notes in Artificial Intelligence, No. 627, pages 101–119, Berlin: Springer-Verlag, http://www.cl.cam.ac.uk/Research/NL/acquilex/papers.html.

Copestake, Ann, Flickinger, Daniel P. and Sag, Ivan A. 1997. Minimal Recursion Semantics: An Introduction, ftp://csli-ftp.stanford.edu/linguistics/sag/mrs.ps.gz. 06.22.97.

Davis, Anthony. 1996. *Lexical Semantics and Linking in the Hierarchical Lexicon*. Ph. D.thesis, Stanford University.

de Geest, Wim. 1970. Infinitiefconstructies bij Verba Sentiendi. *Studia Neerlandica* 3, 33–59.

Devlin, Keith. 1992. *Logic and Information*. Cambridge: Cambridge University Press.

Fillmore, Charles J. 1968. The Case for Case. In Emmon Bach and Robert T. Harms (eds.), *Universals of Linguistic Theory*, pages 1–88, New York: Holt, Rinehart, and Winston.

Fillmore, Charles J. 1977. The Case for Case Reopened. In Peter Cole and Jerrold M. Sadock (eds.), *Grammatical Relations*, volume 8 of *Syntax and Semantics*, pages 59–81, New York, San Francisco, London: Academic Press.

Flickinger, Daniel P. 1987. *Lexical Rules in the Hierarchical Lexicon*. Ph. D.thesis, Stanford University.

Flickinger, Daniel P., Copestake, Ann and Sag, Ivan A. 2000. HPSG analysis of English. In Wahlster (2000), pages 254–263.

Flickinger, Daniel P., Pollard, Carl J. and Wasow, Thomas. 1985. Structure-Sharing in Lexical Representation. In William C. Mann (ed.), *Proceedings of the Twenty-Third Annual Meeting of the Association for Computational Linguistics*, pages 262–267, Association for Computational Linguistics, Chicago, IL.

Ginzburg, Jonathan and Sag, Ivan A. 2001. *English Interrogative Constructions*. Stanford: Center for the Study of Language and Information.

Hinrichs, Erhard, Meurers, Detmar and Wintner, Shuly (eds.). 2000. *Proceedings of the ESSLLI-2000 Workshop on Linguistic Theory and Grammar Implementation*, Birmingham, UK, August 14–18.

Jackendoff, Ray S. 1975. Morphological and Semantic Regularities in the Lexikon. *Language* 51(3), 639–671.

Jackendoff, Ray S. 1977. $\overline{\mathrm{X}}$ *Syntax: A Study of Phrase Structure*. Cambridge: Massachusetts, London: England: The MIT Press.

Johnson, Mark. 1988. *Attribute-Value Logic and the Theory of Grammar*. CSLI Lecture Notes, No. 14, Stanford: Center for the Study of Language and Information.

Kamp, Hans and Reyle, Uwe. 1993. *From Discourse to Logic: Introduction to Modeltheoretic Semantics of Natural Language, Formal Logic and Discourse Representation Theory*. Studies in Linguistics and Philosophy, No. 42, Dordrecht/Boston/London: Kluwer Academic Publishers.

Kiefer, Bernd and Krieger, Hans-Ulrich. 2000. A Context-Free Approximation of Head-Driven Phrase Structure Grammar. In *Proceedings of the 6th International Workshop on Parsing Technologies, IWPT 2000*, pages 135–146.

King, Paul. 1994. An Expanded Logical Formalism for Head-Driven Phrase Structure Grammar. Arbeitspapiere des sfb 340, University of Tübingen, http://www.sfs.nphil.uni-tuebingen.de/~king/. 07.03.98.

Kirsner, Robert S. and Thompson, Sandra A. 1976. The Role of Pragmatic Inference in Semantics: A Study of Sensory Verb Complements in English. *Glossa* 10, 200–240.

Kopru, Selcuk. 1999. *Extendible Structural Transfer: A Case for German to Turkish Translation*. Masters Thesis, Laboratory for the Computational Studies of Language, Middle East Technical University, Ankara, http://www.lcsl.metu.edu.tr/pubs.html. 07.11.2000.

Krieger, Hans-Ulrich. 1994. Derivation Without Lexical Rules. In C.J. Rupp, Michael A. Rosner and Rod L. Johnson (eds.), *Constraints, Language and Computation*, Computation in Cognitive Science, pages 277–313, London/San Diego/New York: Academic Press, eine Version dieses Aufsatzes ist auch als DFKI Research Report RR-93-27 verfügbar. Auch in: IDSIA Working Paper No. 5, Lugano, November 1991.

Kunze, Jürgen. 1991. *Kasusrelationen und semantische Emphase*. studia grammatica XXXII, Berlin: Akademie Verlag.

Meurers, Walt Detmar. 2000. Lexical Generalizations in the Syntax of German Non-Finite Constructions. Arbeitspapiere des SFB 340 145, Eberhard-Karls-Universität, Tübingen.

Müller, Stefan. 1996. The Babel-System—An HPSG Prolog Implementation. In *Proceedings of the Fourth International Conference on the Practical Application of Prolog*, pages 263–277, London, http://www.dfki.de/~stefan/Pub/babel.html. 09.18.2001.

Müller, Stefan. 1999. *Deutsche Syntax deklarativ. Head-Driven Phrase Structure Grammar für das Deutsche*. Linguistische Arbeiten, No. 394, Tübingen: Max Niemeyer Verlag, http://www.dfki.de/~stefan/Pub/hpsg.html. 09.18.2001.

Müller, Stefan. 2000a. *Complex Predicates: Verbal Complexes,* *Resultative Constructions, and Particle Verbs in German*. Habilitationsschrift, Universität des Saarlandes, Saarbrücken, http://www.dfki.de/~stefan/Pub/complex.html. 09.18.2001.

Müller, Stefan. 2000b. Continuous or Discontinuous Constituents? In Hinrichs et. al. (2000), pages 133–152, http://www.dfki.de/~stefan/Pub/discont.html. 09.18.2001.

Müller, Stefan and Kasper, Walter. 2000. HPSG Analysis of German. In Wahlster (2000), pages 238–253.

Neumann, Günter. 1997. Applying Explanation-based Learning to Control and Speeding-up Natural Language Generation. In Philip R. Cohen and Wolfgang Wahlster (eds.), *35th Annual Meeting of the Association for Computational Linguistics. Proceedings of the Conference*, pages 214–221, Madrid: Association for Computational Linguistics.

Neumann, Günter and Flickinger, Daniel P. 1999. Learning Stochastic Lexicalized Tree Grammars from HPSG. http://www.dfki.de/~neumann/publications/new-ps/sltg.ps.gz.

Penn, Gerald and Carpenter, Bob. 1999. ALE for Speech: a Translation Prototype. In *Proceedings of the 6th Conference on Speech Communication and Technology (EUROSPEECH)*, Budapest, Hungary.

Pollard, Carl J. and Sag, Ivan A. 1987. *Information-Based Syntax and Semantics Volume 1 Fundamentals*. CSLI Lecture Notes, No. 13, Stanford: Center for the Study of Language and Information.

Pollard, Carl J. and Sag, Ivan A. 1994. *Head-Driven Phrase Structure Grammar*. Studies in Contemporary Linguistics, Chicago, London: University of Chicago Press.

Sag, Ivan A. 1997. English Relative Clause Constructions. *Journal of Linguistics* 33(2), 431–484, ftp://ftp-csli.stanford.edu/linguistics/sag/rel-pap.ps.gz. 04.13.97.

Sag, Ivan A. and Wasow, Thomas. 1999. *Syntactic Theory: A Formal Introduction*. Stanford: Center for the Study of Language and Information, http://csli-publications.stanford.edu/site/1575861607.html.

Saussure, Ferdinand de. 1915. *Grundlagen der allgemeinen Sprachwissenschaft*. Berlin: Walter de Gruyter & Co, 2. Auflage 1967.

Shieber, Stuart M. 1986. *An Introduction to Unification-Based Approaches to Grammar*. CSLI Lecture Notes, No. 4, Stanford: Center for the Study of Language and Information.

Shieber, Stuart M., Uszkoreit, Hans, Pereira, Fernando, Robinson, Jane and Tyson, Mabry. 1983. The Formalism and Implementation of PATR-II. In *Research on Interactive Acquisition and Use of Knowledge*, pages 39–79, Menlo Park, CA: Artificial Intelligence Center, SRI International.

Siegel, Melanie. 2000. HPSG analysis of Japanese. In Wahlster (2000), pages 264–279.

Uszkoreit, Hans, Backofen, Rolf, Busemann, Stephan, Diagne, Abdel Kader, Hinkelman, Elizabeth A., Kasper, Walter, Kiefer, Bernd, Krieger, Hans-Ulrich, Netter, Klaus, Neumann, Günter, Oepen, Stephan and Spackman, Stephen P. 1994. DISCO—An HPSG-based NLP System and its Application for Appointment Scheduling. In COLING Staff (ed.), *Proceedings of COLING 94*, pages 436–440, Kyoto, Japan: ACL – Association for Computational Linguistics.

Uszkoreit, Hans, Flickinger, Dan, Kasper, Walter and Sag, Ivan A. 2000. Deep Linguistic Analysis with HPSG. In Wahlster (2000), pages 217–238.

Wahlster, Wolfgang (ed.). 2000. *Verbmobil: Foundations of Speech-to-Speech Translation*. Artificial Intelligence, Berlin Heidelberg New York: Springer-Verlag.

Wechsler, Stephen Mark. 1991. *Argument Structure and Linking*.