Head-Driven Phrase Structure Grammar

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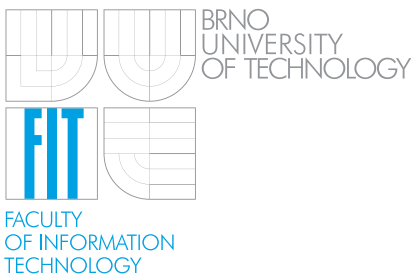

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Outline

- **Introduction**
- **Sign and AVM**
- **HPSG Principles**
- **Lexicon**
- **Examples**

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Head-Driven Phrase Structure Grammar (HPSG)

- Generative grammar
- Non-derivational
  - No notion of deriving one structure from another (such as transformations).
- Declarative constraints
- Unification-based

- Influenced by GPSG.
  - Sometimes considered a direct successor to GPSG, but there is influence from other formalisms as well (such as LFG).

- Emphasis on precise mathematical modeling of linguistic entities.

  - Suitable for computer implementations, often used in practice in NLP.

Components of HPSG

1. Grammar principles
2. Grammar rules
3. Lexical entries

- All these components are formalized as typed feature structures.

Topic

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Sign

- Basic HPSG type
- Collection of information, including
  - Phonology
  - Syntax
  - Semantics

- Every constituent admitted by HPSG is of type sign.
- Constituents have to conform to grammatical principles.

- Two subtypes, further conforming to different constraints.

Sign subtypes

1. Word
   - Conforming to lexical entries
2. Phrase
   - Conforming to grammar rules

Attribute-Value Matrix

- Sign is usually represented by attribute-value matrix (AVM).

Attribute-Value Matrix

$$\begin{bmatrix} \textit{type} & \\ \text{ATTRIBUTE} & \textit{value} \\ \text{ATTRIBUTE} & \textit{value} \\ \vdots & \end{bmatrix}$$

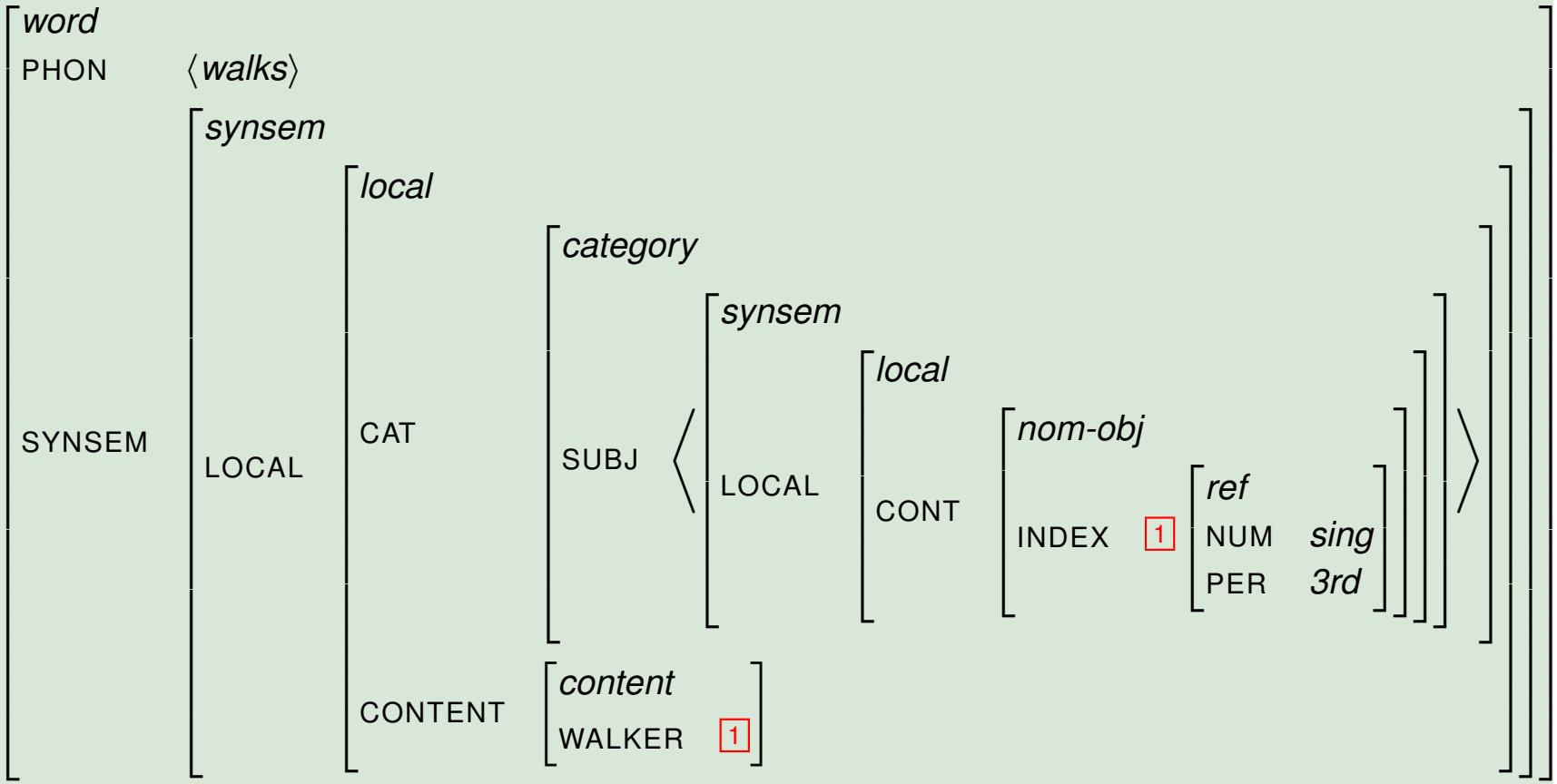
- Note: AVM notations may vary, there may be additional information, type may be omitted,. . .

Types of Values

1. Atomic
2. Complex – the value is itself a feature structure (another AVM)

AVM – Example

Example



Coreferential tag – indicates that certain substructures are identical.

- Here, the AVM which would be the value for WALKER is identical to the tagged AVM in INDEX (number and person must match).

Attributes

- PHON (phonology) – list of phonological descriptions
- SYNSEM (syntax and semantics) – another AMV of type *synsem*

SYNSEM

- HEAD – encodes syntactical features that head and its phrasal constituent have in common
  - Includes information such as part-of-speech, inflectional properties.
- SPR – element that may appear as the specifier in a constituent
- COMPS – elements that may appear as the complements
- ...

- ARG-ST (argument structure) – ordered list of arguments required by the sign
  - Ordered lists are denoted by angled brackets $\langle\rangle$

AVM – Example 2

Example

$$\begin{bmatrix} \textit{word} & & \\ \text{PHON} & \langle \textit{letter} \rangle & \\ \text{SYNSEM} & \begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{noun} & \\ \text{AGR} & \boxed{1}\begin{bmatrix} \textit{3sng} & \\ \text{GEND} & \textit{neut} \end{bmatrix} \end{bmatrix} \\ \text{SPR} & \boxed{2}\left\langle \begin{bmatrix} \text{AGR} & \boxed{1} \\ \text{COUNT} & + \end{bmatrix} \right\rangle \\ \text{COMPS} & \boxed{3}\langle (\text{PP}) \rangle \end{bmatrix} \\ \text{ARG-ST} & \langle \boxed{3}, \boxed{2} \rangle \end{bmatrix}$$

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Sign Unification

- We combine information from two AVM descriptions.
- Similar to feature unification in GPSG.

Example

$$\begin{bmatrix} \text{NUM} & \textit{sing} \end{bmatrix} \qquad \begin{bmatrix} \text{PER} & \textit{3rd} \end{bmatrix}$$

$$\begin{bmatrix} \text{NUM} & \textit{sing} \\ \text{PER} & \textit{3rd} \end{bmatrix}$$

- If features contradict each other, unification fails.

Example

$$\begin{bmatrix} \text{NUM} & \textit{sing} \end{bmatrix} \qquad \begin{bmatrix} \text{NUM} & \textit{plur} \end{bmatrix}$$

HPSG Principles

- Grammar rules and principles determine well-formed expressions of a language.
- Formally, principles are implemented by feature structures.
  - This means we can also describe them using AVMs.

Some HPSG Principles

- Head Feature Principle
- Valence Principle
- Immediate Dominance Principle
- Argument Realization Principle
- ...

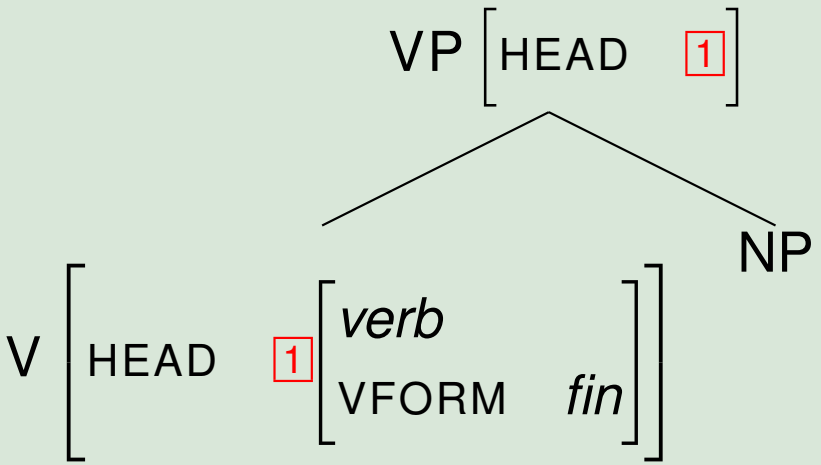
- Checking of principles is done by unification – if unification between the feature structures of the principle and a particular sign fails, then the principle is not satisfied.

Head Feature Principle

The HEAD value of a headed phrase is identified with that of its head-child.

- Ensures that the HEAD properties (part-of-speech, verb inflection,...) of head are projected onto headed phrases.

Example

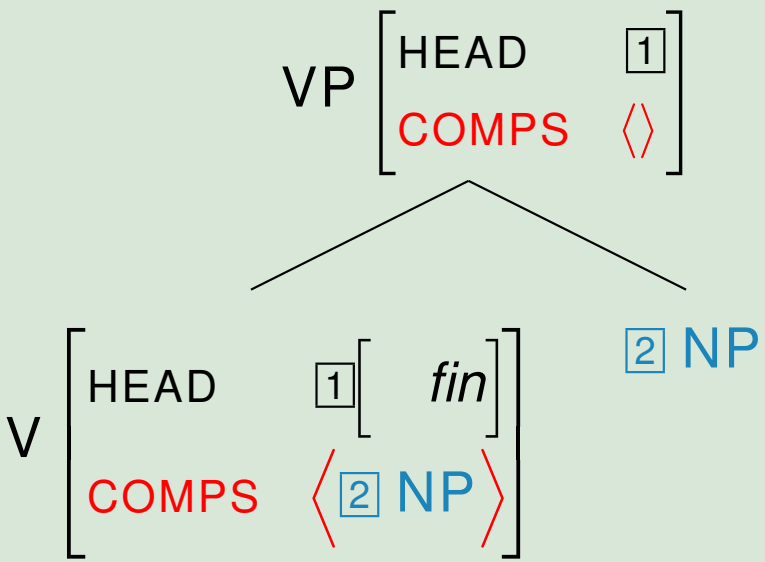


Valence Principle

For each valence feature *F*, the *F* value of a headed phrase is the child's *F* value minus the realized non-head-children.

- "Checks off" the combinatorial requirements of lexical head, encoded through valence features (such as SPR, COMP).

Example



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- Lexical entries in HPSG are also represented as feature structures (using AVM).

Example

gave

$$\begin{bmatrix} \text{HEAD} & \begin{bmatrix} \textit{verb} \\ \text{VFORM} \quad \textit{fin} \end{bmatrix} \\ \text{SUBJ} & \langle \text{NP}[\textit{nom}] \rangle \\ \text{COMPS} & \langle \text{NP}[\textit{acc}], \text{PP}[\textit{to}] \rangle \end{bmatrix}$$

books

$$\begin{bmatrix} \text{HEAD} & \textit{noun} \\ \text{SPEC} & \langle \text{DetP} \rangle \\ \text{COMPS} & \langle\rangle \end{bmatrix}$$

- Lexical entries are fully inflected (entries for *give*, *gave*, *given*...).

Horizontal and Vertical Redundancy

- If the lexicon were just an unorganized collection of lexical entries, there would be redundancy, important generalizations would be missed.

Horizontal redundancy

Separate entries for items related according to some recurrent pattern.

- For example plural inflection (*book* and *books*) or active and passive form of verb.

Vertical redundancy

Listing all linguistic information shared by whole classes of words in each entry separately.

- For example, all singular count nouns in English need a determiner.

Hierarchical Classification

- Hierarchical classification deals with vertical redundancy.

Hierarchical Classification

- We assign a type (sort) to words of specific categories.
- Supersort – category which covers a group of words.
- Constraints that are shared by category of words are assigned to supersort.
- Each lexical entry lists its sort – the constrains of the category are then inherited from its supersort.
  - We do not need to list these constraints for each entry separately.

Lexical Rules

- Lexical rules deal with horizontal redundancy.

Lexical Rules

- Generate new lexical entries from basic entries.
  - Reduces the number of entries we need to store.

Example

Passive lexical rule:

$$\begin{bmatrix} \textit{trans-verb} & \\ \text{PHON} & \boxed{1} \\ \text{SUBJ} & \langle \text{NP}_i \rangle \\ \text{COMPS} & \langle \boxed{2}, \ldots \rangle \end{bmatrix} \rightarrow \begin{bmatrix} \textit{passive-verb} & \\ \text{PHON} & F_{pass}(\boxed{1}) \\ \text{SUBJ} & \langle \boxed{2} \rangle \\ \text{COMPS} & \langle \ldots, (\text{PP}_i) \rangle \end{bmatrix}$$

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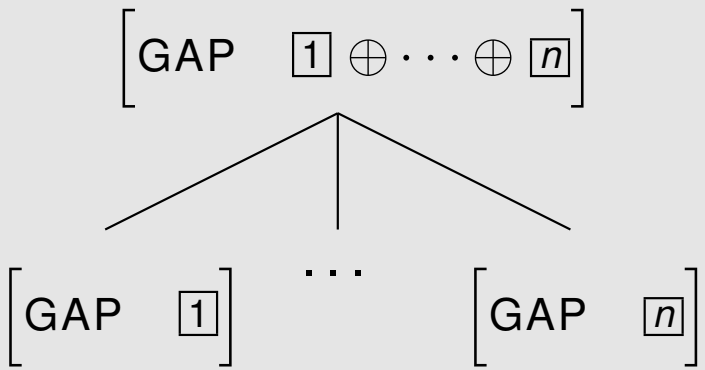
Example: Long Distance Dependencies

- To deal with long distance dependencies, HPSG uses GAP feature.
- ARG-ST – arguments required by the argument structure.
- Missing arguments appear in the value of GAP.

- The GAP feature percolates up to the parent node.

GAP Principle



Example: Long Distance Dependencies

- In a well-formed sentences the GAP feature must be satisfied.
- We can apply the head filler rule.

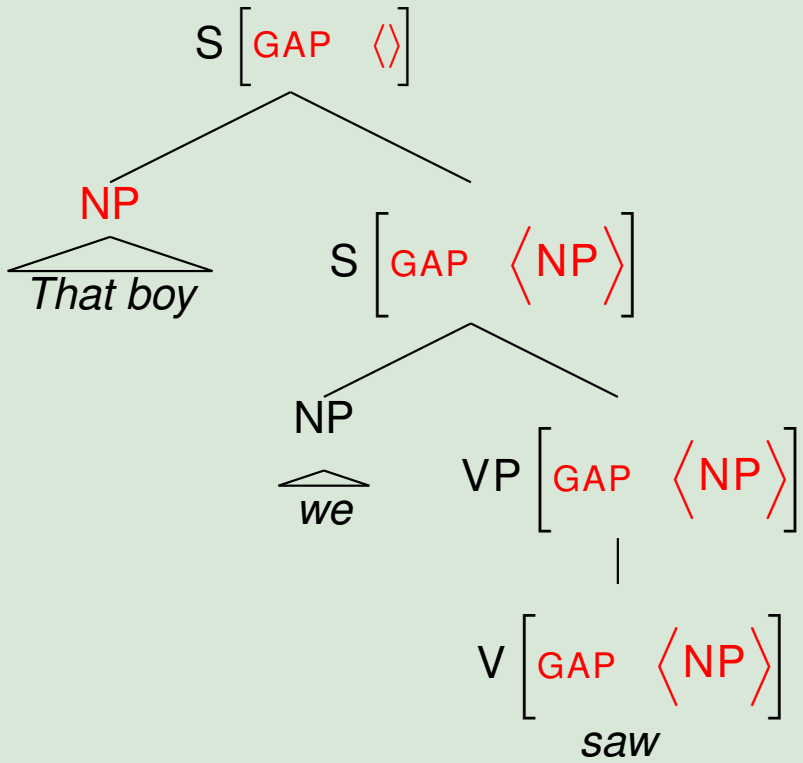
Head Filler Rule

$$\begin{bmatrix} \textit{phrase} \\ \text{GAP} \quad \langle\rangle \end{bmatrix} \rightarrow \boxed{1} \begin{bmatrix} \textit{phrase} \\ \text{GAP} \quad \langle\rangle \end{bmatrix} \quad \text{H} \begin{bmatrix} \textit{phrase} \\ \text{FORM} \quad \textit{fin} \\ \text{SPR} \quad \langle\rangle \\ \text{GAP} \quad \left\langle \boxed{1} \right\rangle \end{bmatrix}$$

Example: Long Distance Dependencies

Example

That boy we saw



1. The verb *see* requires a complement which is not present – GAP feature is filled (NP is required by ARG-ST of the verb).
2. GAP feature percolates up.
3. At the sentence level, we can apply the head filler rule – GAP becomes empty.

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