Unbounded Dependencies

- **Definition:**

  A dependency between two elements in a string is unbounded if the structural connection between the two elements has to be defined recursively.

- Dependency between overt dislocated element and governor

  (9) *What* do you think Tigger *ate*

- Dependency involving non-overt dislocated element

  (10) Robin brought the thistles ε he knows that Tiggers like best to *eat*

- Agreement dependency between noun and relative proform

  (11) the *boy* with *whose* best friend's tiger ...

- Dependency between clause node and question proform

  (12) Robin asked with *whose* best friend's tiger ...

Treatment of UD in HPSG

- UD is split into three parts:
  - Introduction of Filler (dislocated element)
  - Transportation of Filler (`SLASH` percolation)
  - Cancellation of Filler (integration into structure)
- Structure of NON-LOCAL Information:

$$ {}_{sign}\begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix} \texttt{LOC} & \begin{bmatrix} \texttt{CAT} \ldots \end{bmatrix} \\ \texttt{NONLOC} & \begin{bmatrix} \texttt{SLASH} & \ldots \\ \texttt{REL} & \ldots \\ \texttt{QUE} & \ldots \end{bmatrix} \end{bmatrix} \end{bmatrix} $$

Some Issues:

- Is there more than one dislacated element:

  Is the value of the `NON-LOCAL` features a feature structure, a set or a list of feature structures?

- Is the cancellation of the Filler information performed by means of empty elements / traces or without traces?

- Along what structural paths are `NON-LOCAL` features percolated?

  (Is a foot-feature principle necessary?)

Grammar Rule 6: Filler-Head Rule (simplified version)

- Combines dislocated element with head
- Condition:

  Head must have empty `SUBCAT` – list
- Some instances in terms of phrase structure rules:

$$\begin{aligned} \overline{\mathrm{S}} &\rightarrow \mathrm{XP} \quad \mathrm{S} \\ \overline{\mathrm{VP}} &\rightarrow \mathrm{XP} \quad \mathrm{VP} \end{aligned}$$

- In informal re-write notation

$$[\texttt{SLASH}\ \{\ \}] \rightarrow \mathrm{F} \quad \mathrm{H}[\texttt{SUBCAT}\ \langle\ \rangle]$$

- Representation in AVM terms (preliminary version)

$$\begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix} \texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \{\ \}\end{bmatrix}\end{bmatrix} \\ \texttt{DTRS} & \begin{bmatrix} \texttt{HEAD-DTR} & \begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix} \texttt{LOC} & \begin{bmatrix}\texttt{CAT} & \begin{bmatrix}\texttt{SUBCAT}\ \langle\ \rangle\end{bmatrix}\end{bmatrix} \\ \texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \{\boxed{1}\ \}\end{bmatrix}\end{bmatrix}\end{bmatrix} \\ \texttt{FILLER-DTR} & \begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix}\texttt{LOC}\ \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

SLASH Transportation

Nonlocal Feature Principle (simplified version)

- The value of each nonlocal feature on a phrasal sign is the union of the values on the daughters.

Example:

$$
\begin{bmatrix}
\texttt{SYNSEM} & \begin{bmatrix}\texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \textit{union}(\boxed{1}, \boxed{2})\end{bmatrix}\end{bmatrix} \\
\texttt{DTRS} & \begin{bmatrix}
\texttt{HEAD-DTR} & \begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix}\texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix} \\
\texttt{COMP-DTRS} & \begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix}\texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \boxed{2}\end{bmatrix}\end{bmatrix}\end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

SLASH Cancellation

- At any arbitrary node in the structure which meets the requirements the information about the Filler Daughter can be accessed by means of a trace:

Lexical Entry for Trace

$$\begin{bmatrix} \texttt{PHON} & \langle\ \rangle \\ \texttt{SYNSEM} & \begin{bmatrix} \texttt{NONLOC} & \begin{bmatrix} \texttt{SLASH} & \{\boxed{1}\ \} \end{bmatrix} \\ \texttt{LOC} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Constraints on occurence of traces by means of:

Trace Principle

- Every trace must be strictly subcategorized by a substantive head, i.e. its `SYNSEM` value must occur on a `SUBCAT` list.

Problem:

- Filler-Head-Rule as it is specified does not obey Nonlocal Principle

- `SLASH` value on the mother should not be empty (according to NLP)

- `SLASH` must be stopped from percolating further up the tree

- Solution: Split of information which is to be percolated and which is already bound:

$$
{}_{sign}\left[\begin{array}{ll}\mathtt{SYNSEM} & \left[\begin{array}{ll}\mathtt{LOC} & \left[\mathtt{CAT}\ \ldots\right] \\ \mathtt{NONLOC} & \left[\begin{array}{ll}\mathtt{INHERIT} & \left[\begin{array}{ll}\mathtt{SLASH} & \ldots \\ \mathtt{REL} & \ldots \\ \mathtt{QUE} & \ldots\end{array}\right] \\ \mathtt{TO\text{-}BIND} & \left[\begin{array}{ll}\mathtt{SLASH} & \ldots \\ \mathtt{REL} & \ldots \\ \mathtt{QUE} & \ldots\end{array}\right]\end{array}\right]\end{array}\right]\end{array}\right]
$$

Nonlocal Feature Principle (modified version)

- For each nonlocal feature, the `INHERIT` value on the mother is the union of the `INHERIT` values on the daughters minus the `TO-BIND` values on the daughters / on the `HEAD-DTR`.

Filler-Head-Rule (modified version)

$$
\begin{bmatrix}
\mathtt{SYNSEM} & \begin{bmatrix} \mathtt{NONLOC} & \begin{bmatrix} \mathtt{INHERIT} & \begin{bmatrix} \mathtt{SLASH}\ \{\ \} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\
\mathtt{DTRS} & \begin{bmatrix}
\mathtt{HEAD\text{-}DTR} & \begin{bmatrix} \mathtt{SYNSEM} & \begin{bmatrix}
\mathtt{LOC} & \begin{bmatrix} \mathtt{CAT} & \begin{bmatrix} \mathtt{SUBCAT}\ \langle\ \rangle \end{bmatrix} \end{bmatrix} \\
\mathtt{NONLOC} & \begin{bmatrix} \mathtt{TO\text{-}BIND} & \begin{bmatrix} \mathtt{SLASH}\ \{\boxed{1}\ \} \end{bmatrix} \\ \mathtt{INHERIT} & \begin{bmatrix} \mathtt{SLASH}\ \{\boxed{1}\ \} \end{bmatrix} \end{bmatrix}
\end{bmatrix} \end{bmatrix} \\
\mathtt{FILLER\text{-}DTR} & \begin{bmatrix} \mathtt{SYNSEM} & \begin{bmatrix} \mathtt{LOC}\ \boxed{1} \end{bmatrix} \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Lexical Entry for Trace (final version)

$$\begin{bmatrix} \texttt{PHON} & \langle\,\rangle \\ \texttt{SYNSEM} & \begin{bmatrix} \texttt{NONLOC} & \begin{bmatrix} \texttt{INHERIT} & \begin{bmatrix} \texttt{SLASH} & \{\boxed{1}\} \\ \texttt{REL} & \{\,\} \\ \texttt{QUE} & \{\,\} \end{bmatrix} \\ \texttt{TO-BIND} & \begin{bmatrix} \texttt{SLASH} & \{\,\} \\ \texttt{REL} & \{\,\} \\ \texttt{QUE} & \{\,\} \end{bmatrix} \end{bmatrix} \\ \texttt{LOC} & \boxed{1} \end{bmatrix} \end{bmatrix}$$

Relative Clause Constructions

Issues:

- Agreement between head noun and relative pronoun

  (13) the book, which / *who John bought ...

- Percolation of pronoun agreement to "relative phrase"

  Pied Piping:

  (14) .. the book, [the picture on the cover of *which*] is horrible,

- Relative Proform has to appear in phrase in left-peripheral position of finite clause

  (15) * the book, Mary bought *which* yesterday, was expensive

Rule for Adjunction of Relative Clause

$$
\begin{bmatrix}
\texttt{SYNSEM} & \begin{bmatrix}
\texttt{NONLOC} & \begin{bmatrix} \texttt{INHERIT} & \begin{bmatrix} \texttt{REL} & \{\ \} \end{bmatrix} \end{bmatrix} \\
\texttt{LOC} & \begin{bmatrix} \texttt{CAT} & \begin{bmatrix} \texttt{SUBCAT} & \langle\ \rangle \end{bmatrix} \end{bmatrix}
\end{bmatrix} \\
\texttt{DTRS} & \begin{bmatrix}
\texttt{HEAD-DTR} & \begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix} \texttt{LOC} & \begin{bmatrix} \texttt{CAT} & \begin{bmatrix} \texttt{HEAD} & \begin{bmatrix} \texttt{AGR} & \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\
\texttt{REL-DTR} & \begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix}
\texttt{NONLOC} & \begin{bmatrix}
\texttt{INHERIT} & \begin{bmatrix} \texttt{REL} & \left\{ \boxed{2} \begin{bmatrix} \texttt{AGR} & \boxed{1} \end{bmatrix} \right\} \end{bmatrix} \\
\texttt{TO-BIND} & \begin{bmatrix} \texttt{REL} & \{ \boxed{2}\ \} \end{bmatrix}
\end{bmatrix} \\
\texttt{LOC} & sfin\begin{bmatrix}\ \end{bmatrix}
\end{bmatrix} \end{bmatrix}
\end{bmatrix}
\end{bmatrix}
$$

Lexical Entry for Relative Pronoun

$$\left[\mathtt{SYNSEM}\left[\begin{array}{ll}\mathtt{LOC} & \left[\mathtt{CAT}\left[\mathtt{HEAD}\left[\mathtt{AGR}\ \boxed{1}\right]\right]\right]\\ \mathtt{NONLOC} & \left[\begin{array}{ll}\mathtt{INHERIT} & \left[\mathtt{REL}\ \left\{\left[\mathtt{AGR}\ \boxed{1}\right]\right\}\right]\\ \mathtt{TO\text{-}BIND} & \left[\mathtt{REL}\ \{\ \}\right]\end{array}\right]\end{array}\right]\right]$$

Filler-Head-Rule (modified version)

$$
\left[\begin{array}{ll}
\texttt{SYNSEM} & \left[\texttt{NONLOC}\ \left[\texttt{INHERIT}\ \left[\texttt{SLASH}\ \{\ \}\right]\right]\right] \\
\texttt{DTRS} & \left[\begin{array}{ll}
\texttt{HEAD-DTR} & \left[\texttt{SYNSEM}\ \left[\begin{array}{ll}
\texttt{LOC} & \left[\texttt{CAT}\ \left[\texttt{SUBCAT}\ \langle\ \rangle\right]\right] \\
\texttt{NONLOC} & \left[\texttt{TO-BIND}\ \left[\begin{array}{ll} \texttt{SLASH} & \{\boxed{1}\} \\ \texttt{REL} & \{\ \} \end{array}\right]\right] \\
\texttt{INHERIT} & \left[\begin{array}{ll} \texttt{SLASH} & \{\boxed{1}\} \\ \texttt{REL} & \{\ \} \end{array}\right]
\end{array}\right]\right] \\
\texttt{FILLER-DTR} & \left[\texttt{SYNSEM}\ \left[\texttt{LOC}\ \boxed{1}\right]\right]
\end{array}\right]
\end{array}\right]
$$

Left Peripheral Position of "Relative Phrase"

- Relative Phrase must not be embedded in finite VP

  (16) * the book, John [bought *which*], was expensive

- Relative Phrase may be either in Subject or in Topic-Position

  (17) the book, [on the cover of *which*] was a picture, was expensive

- CONDITIONS:
  - `INHERIT REL` value for finite VPs must be empty.
  - `REL` must be a singleton set (in English)

$$\left[\texttt{SYNSEM}\quad {}_{vfin}\!\left[\begin{array}{ll}\texttt{LOC} & \left[\texttt{CAT}\left[\texttt{SUBCAT}\ \langle[\ ]\rangle\right]\right]\\ \texttt{NONLOC} & \left[\texttt{INHERIT}\left[\texttt{REL}\ \{\ \}\right]\right]\end{array}\right]\right]$$

Lexicalized Version of UD

- For languages with less freedom of extraction (e.g. no extraction out of PP or NP complements) a simplified version can be assumed.

SLASH Principle for German

- In a headed structure the SLASH value of the mother is token identical with the SLASH value of the HEAD-DTR

$$\begin{bmatrix}\texttt{DTRS}\ {}_{\textit{headed-structure}}\begin{bmatrix}\ \end{bmatrix}\end{bmatrix} \Rightarrow$$

$$\begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix}\texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \boxed{1}\end{bmatrix}\end{bmatrix} \\ \texttt{DTRS} & \begin{bmatrix}\texttt{HEAD-DTR} & \begin{bmatrix}\texttt{SYNSEM} & \begin{bmatrix}\texttt{NONLOC} & \begin{bmatrix}\texttt{SLASH}\ \boxed{1}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}\end{bmatrix}$$

SLASH Termination Rule

- No traces and empty nodes for `SLASH` cancellation

- Items on the `SLASH` list are taken directly off the `SUBCAT` list of the verb.

$$\begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix} \texttt{NONLOC} & \begin{bmatrix} \texttt{SLASH}\ \langle \boxed{1} \rangle \end{bmatrix} \\ \texttt{LOC} & \begin{bmatrix} \texttt{CAT} & \begin{bmatrix} \texttt{SUBCAT}\ less(\boxed{1}, \boxed{2}) \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \texttt{DTRS} & \begin{bmatrix} \texttt{HEAD-DTR} & \begin{bmatrix} \texttt{SYNSEM} & \begin{bmatrix} \texttt{NONLOC} & \begin{bmatrix} \texttt{SLASH}\ \langle\ \rangle \end{bmatrix} \\ \texttt{LOC} & \begin{bmatrix} \texttt{CAT} & \begin{bmatrix} \texttt{SUBCAT}\ \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

Function *less* : subtract element from list

e.g. $less(\text{ b}, \langle a, b, c \rangle) = \langle a, c \rangle$

Crossing the Boundary

- Crossing of clausal boundaries is determined lexically.

- "Simple verbs" have a empty **SLASH** feature in their lexical entry.

$$\left[\texttt{SYNSEM}\left[\texttt{NONLOC}\left[\texttt{SLASH}\ \langle\ \rangle\right]\right]\right]$$

- "Bridge verbs" co-index their **SLASH** value with the **SLASH** value of their clausal complements.

$$\left[\texttt{SYNSEM}\left[\begin{array}{ll}\texttt{NONLOC} & \left[\texttt{SLASH}\ \boxed{1}\right] \\ \texttt{LOC} & \left[\texttt{CAT}\left[\texttt{SUBCAT}\ \left\langle \ldots,\ {}_{sent}\left[\texttt{NONLOC}\left[\texttt{SLASH}\ \boxed{1}\right]\right]\right\rangle\right]\right]\end{array}\right]\right]$$