A semantic "Trampe" for HPSG: Easy ways from bottom to top and back in Trondheim

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1 Introduction

(1) a. Every student reads some book.

b. $\forall x[\mathsf{student}'(x) \rightarrow \exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$

c. $\exists y[\mathsf{book}'(y) \wedge \forall x[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x,y)]]$

Easy Ways:

- Standard semantic representations for HPSG
- Standard model-theoretic interpretation of the semantic representations
- Use of HPSG-specific specification techniques to make linguistic theories at the syntax-semantics interface as elegant as possible
- Classification of existing semantic representation languages in HPSG
- Illustration: a theory of negative concord in Polish

2 Prerequisites

2.1 Reminder 1: The Formal Framework of HPSG 94

Grammars and their denotation:

- A grammar consists of a **signature** and a **theory**
  - Signature: sort hierarchy, set of attributes, set of relation symbols, arity of relations, appropriateness conditions (sometimes called *feature declarations*)
  - Theory: a set of descriptions (the *principles* of grammar)
- A **model** of a grammar is a collection of objects whose components are configured in accordance with the signature; and all objects satisfy each description in the theory.
- Currently, there are essentially two explanations of the meaning of an HPSG 94 grammar:
  - An **exhaustive model** contains "instances" of all objects that are licensed by the theory. One of the exhaustive models of the class of exhaustive models of a grammar is understood as containing the **possible tokens** of the natural language under consideration (King, 1999).
  - A collection of structures that can be construed in various ways is understood as the **types** of the natural language under consideration. The types are taken to be (a certain kind of) feature structures in Pollard and Sag (1994), but not in Pollard (1999), which takes a slightly different (more agnostic) ontological perspective.
- Our view: We take *Relational Speciate Re-entrant Language* (RSRL, Richter et al. (1999); Richter (2000)) as the description language for HPSG grammars.

2.2 Reminder 2: The Structure of Signs HPSG 94

Expressed within the formal framework, we find universal assumptions about the structure of linguistic signs. The structure of signs in HPSG 94 is best visualized with a sketch of a description of all possible signs:

$$\begin{bmatrix} \textit{sign} & \\ \textsc{phonology} & \textbf{phonological structure} \\ \textsc{synsem} & \begin{bmatrix} \textsc{local} & \begin{bmatrix} \textsc{category} & \textbf{syntactic structure} \\ \textsc{content} & \textbf{semantic structure} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

2.3 Reminder 3: Underspecification

The most natural notion of "*underspecification*" in HPSG is *underspecification at the description level.*

- *Underspecification in the lexicon*: a lexical entry is a description. A lexical entry is underspecified if there is some attribute whose value is not fully determined by the lexical entry. For example, for auxiliary verbs in English, the grammar in Pollard and Sag (1994) leaves the value of the INVERTED attribute underspecified. In every sentence, however, the value of this attribute is either *plus* or *minus*.
- Typical semantic instances of that kind of underspecification in the lexicon of Pollard and Sag (1994) are "CONTENT raisers" like the verbs *to* and *be*.
- In the grammar of Pollard and Sag (1994) sentence (1) receives a single syntactic analysis. The SEMANTICS PRINCIPLE leaves some freedom as to the place where quantifiers are inserted into the CONTENT value of a sign. In this sense, the SEMANTICS PRINCIPLE is underspecified.

3 Assumptions about Semantic Representations

3.1 Technicalities

- We assume that the CONTENT value of a sign is a **logical form**. In particular, we assume the language Ty2 of (Gallin, 1975), which is similar to Intensional Logic (Montague, 1974) but has technical advantages.
- Furthermore, we take it as given that we can express a grammar of Ty2 in RSRL. For the necessary proofs, see Sailer (2000).

(2) A description that denotes the term $\lambda x_e.\mathsf{student}'_{et}(x_e)$:

$$\begin{bmatrix} \textit{abstraction} & & \\ \textsc{type} & \boxed{0} & \begin{bmatrix} \textit{c-type} & \\ \textsc{in} & \boxed{1}\ \textit{entity} \\ \textsc{out} & \boxed{2}\ \textit{truth} \end{bmatrix} \\ \textsc{var} & \boxed{3} & \begin{bmatrix} \textit{var} & \\ \textsc{type} & \boxed{1} \end{bmatrix} \\ \textsc{arg} & & \begin{bmatrix} \textit{application} & \\ \textsc{func} & \begin{bmatrix} \textit{student} & \\ \textsc{type}\ \boxed{0} & \begin{bmatrix} \textit{c-type} & \\ \textsc{in} & \boxed{1} \\ \textsc{out} & \boxed{2} \end{bmatrix} \end{bmatrix} \\ \textsc{arg} & \boxed{3} \end{bmatrix} \end{bmatrix}$$

3.2 A Taxonomy

Three parameters for semantic systems for HPSG:

1. **discontinuous representation**: the semantic contribution of words is not a single term but a collection of terms; these terms are usually discontinually distributed over the logical form of bigger syntactic units.
2. **underspecified denotation**: the CONTENT value represents an underspecified semantic term.
3. **indirect representation**: meta-variables occur in the CONTENT value.

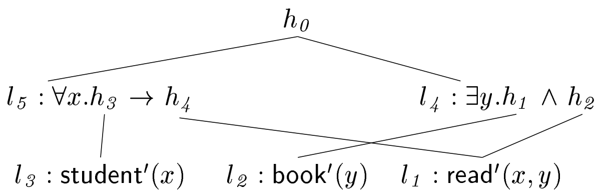
Table 1: Classification of semantic representations in HPSG 94

Approach	underspecified den.	indirect repr.	discontinuous repr.
Ty2U	+	+	+
Ty2U^P	-	+	+
LRS	-	-	+
LF-Ty2	-	-	-

4 Underspecified Denotation: Ty2U

4.1 Bos (1996)

(3) An underspecified representation of the sentence *every student reads some book.*:



Underspecified Representation:

(4) a. A set of holes:
$\{h_0, h_1, h_2, h_3, h_4\}$,

b. A set of labelled formulae:
$\{l_1 : \mathsf{read}'(x,y), \quad l_2 : \mathsf{book}'(y), \quad l_3 : \mathsf{student}'(x), l_4 : \exists y.h_1 \wedge h_2, \quad l_5 : \forall x.h_3 \rightarrow h_4\}$

c. A set of constraints:
$\{l_1 \leq h_0, \quad l_2 \leq h_0, \quad l_4 \leq h_0, \quad l_2 \leq h_1, \quad l_1 \leq h_2, \quad l_3 \leq h_0, \quad l_5 \leq h_0, \quad l_3 \leq h_3, \quad l_1 \leq h_4\}$

Plugging: bijection from holes to labels

(5) a. $\forall x.[\mathsf{student}'(x) \rightarrow \exists y.[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$
$P1 = \{h_0 = l_5, \quad h_1 = l_2, \quad h_2 = l_1, \quad h_3 = l_3, \quad h_4 = l_4\}$

b. $\exists y.[\mathsf{book}'(y) \wedge \forall x.[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x,y)]]$
$P2 = \{h_0 = l_4, \quad h_1 = l_2, \quad h_2 = l_5, \quad h_3 = l_3, \quad h_4 = l_1\}$

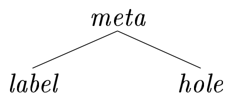
4.2 A Sketch

Signature for **underspecified representations**:

(6) a. *undersp.-repr*

undersp.-repr	HOLES	*list(hole)*
	LABELS	*list(label)*
	CONSTR(AINTS)	*list(constraint)*
	MAIN	*label*
	TOP	*hole*

b.



c. *constraint* A1 *meta*
A2 *meta*

Relevant parts of some lexical entries:

(7) a.

$$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{reads} \rangle \\ \textsc{synsem loc} & \left[\begin{array}{ll} \textsc{cat} & \left[\begin{array}{ll}\textsc{head} & \textit{verb} \\ \textsc{subcat} & \left\langle \text{NP, NP}\right\rangle\end{array}\right] \\ \textsc{content} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{ur}} \\ \textsc{holes} & \langle h_0\rangle \\ \textsc{labels} & \left\langle \boxed{1}\lambda y\lambda x.\mathsf{read}'(x,y)\right\rangle \\ \textsc{constr} & \left\langle \boxed{1} \leq h_0 \right\rangle \\ \textsc{main} & \boxed{1} \\ \textsc{top} & h_0 \end{array}\right]\end{array}\right]\end{array}\right]$$

b.

$$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{book} \rangle \\ \textsc{synsem loc} & \left[\begin{array}{ll} \textsc{cat head} & \textit{noun} \\ \textsc{content} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{ur}} \\ \textsc{holes} & \langle h_0\rangle \\ \textsc{labels} & \left\langle \boxed{2}\lambda y.\mathsf{book}'(y)\right\rangle \\ \textsc{constr} & \left\langle \boxed{2} \leq h_0 \right\rangle \\ \textsc{main} & \boxed{2} \\ \textsc{top} & h_0 \end{array}\right]\end{array}\right]\end{array}\right]$$

c.

$$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{student} \rangle \\ \textsc{synsem loc} & \left[\begin{array}{ll} \textsc{cat head} & \textit{noun} \\ \textsc{content} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{ur}} \\ \textsc{holes} & \langle h_0\rangle \\ \textsc{labels} & \left\langle \boxed{3}\lambda x.\mathsf{student}'(x)\right\rangle \\ \textsc{constr} & \left\langle \boxed{3} \leq h_0 \right\rangle \\ \textsc{main} & \boxed{3} \\ \textsc{top} & h_0 \end{array}\right]\end{array}\right]\end{array}\right]$$

d.

$$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{some} \rangle \\ \textsc{synsem loc} & \left[\begin{array}{ll} \textsc{cat head} & \textit{determiner} \\ \textsc{content} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{ur}} \\ \textsc{holes} & \left\langle h_0, h_1, h_2\right\rangle \\ \textsc{labels} & \left\langle \boxed{4}\exists y[h_1 \wedge h_2]\right\rangle \\ \textsc{contr} & \left\langle \boxed{4} \leq h_0 \right\rangle \\ \textsc{main} & \boxed{4} \\ \textsc{top} & h_0 \end{array}\right]\end{array}\right]\end{array}\right]$$

e.

$$\left[\begin{array}{ll} \textsc{phon} & \langle \textit{every} \rangle \\ \textsc{synsem loc} & \left[\begin{array}{ll} \textsc{cat head} & \textit{determiner} \\ \textsc{content} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{ur}} \\ \textsc{holes} & \left\langle h_0, h_3, h_4\right\rangle \\ \textsc{labels} & \left\langle \boxed{5}\forall y[h_3 \rightarrow h_4]\right\rangle \\ \textsc{contr} & \left\langle \boxed{5} \leq h_0 \right\rangle \\ \textsc{main} & \boxed{5} \\ \textsc{top} & h_0 \end{array}\right]\end{array}\right]\end{array}\right]$$

(8) The SEMANTICS PRINCIPLE:

In each phrase:

1. HOLES: is a concatenation of the values at the daughters
2. LABELS: is a concatenation of the values at the daughters
3. MAIN: is identical to the head daughter's value
4. TOP: is identical at the mother and the daughters
5. CONSTR: contains exactly
   (a) all elements of the daughters' CONSTR lists,
   (b) in *head-adjunct-phrase*:
   head's main $\leq$ adjunct's main
   adjunct's main $\leq$ top

(c) in *head-complement-phrase*:
head's main $\leq$ complement's nucleus
complement's main $\leq$ top

(d) in a nominal projection:
head's main $\leq$ quantifier's restriction

(9) a. description of the CONTENT value for the sentence *Every student reads some book*:

$$\begin{bmatrix} \text{HOLES} & \langle h_0, h_1, h_2, h_3, h_4 \rangle \\ \text{LABELS} & \langle \boxed{1}, \boxed{2}, \boxed{3}, \boxed{4}, \boxed{5} \rangle \\ \text{CONSTR} & \langle \boxed{1} \leq h_0, \boxed{2} \leq h_0, \boxed{4} \leq h_0, \boxed{2} \leq h_1, \boxed{1} \leq h_2, \boxed{3} \leq h_0, \boxed{5} \leq h_0, \boxed{3} \leq h_3, \boxed{1} \leq h_4 \rangle \\ \text{MAIN} & \boxed{1} \\ \text{TOP} & h_0 \end{bmatrix}$$

b. This describes an underspecified representation which is like (4).

c. This underspecified representation has the pluggings in (5)

4.3 Problematic Data

In Ty2U scope resolution is not part of the grammar. Therefore, it is impossible to exclude a sentence whose ungrammaticality is due to conflicting scoping requirements.

Example 1: interrogatives in German (Beck, 1996)

(10) a. * Wann hat niemand wem geholfen?
when has nobody whom helped

b. Wann hat wem niemand geholfen?
when has whom nobody helped
'When did nobody help whom'
$\lambda p.\exists t \exists x[p = \lambda w.\neg\exists y[y \text{ helps } x \text{ at } t]]$

Assumptions:

1. Assume a quantificational analysis of interrogatives, i.e.,
wer (*who*) $\rightsquigarrow$ $\lambda P \lambda Q \lambda p.\exists x[P_w(x) \wedge p = \lambda w.Q_w(x)]$.

2. Assume that the relative scope of a negation and a quantifier is (largely) determined by word order.

3. The quantifier contributed by the in-situ interrogative pronoun *wem* ($\exists y$) must outscope the interrogative operator ($p = \lambda w.\phi$).

→ With (1) and (2) it follows that
(i) the negation must be in the scope of the fronted interrogative pronoun, and (ii) the quantifier contributed by the in-situ interrogative must be in the scope of the negation.

With (3) it follows that the quantifier contributed by *wem* must outscope the interrogative operator.

Thus, we get a contradiction for (10a) but nor for (10b).

Example 2: n-words in Polish (Przepiórkowski and Kupść, 1999)

In Polish, the preverbal particle *nie* is systematically ambiguous between eventuality negation and non-eventuality negation (pleonastic or other). N-words such as *nikt* (*no-one*) must co-occur with the particle *nie*, but can do so only in its eventuality negation reading.

(11) a. Omal jej nie przeróciłem.
almost her NM I overturned
'I almost knocked her over.'

b. ?* Omal nikogo nie przeróciłem.
almost nobody not I overturned

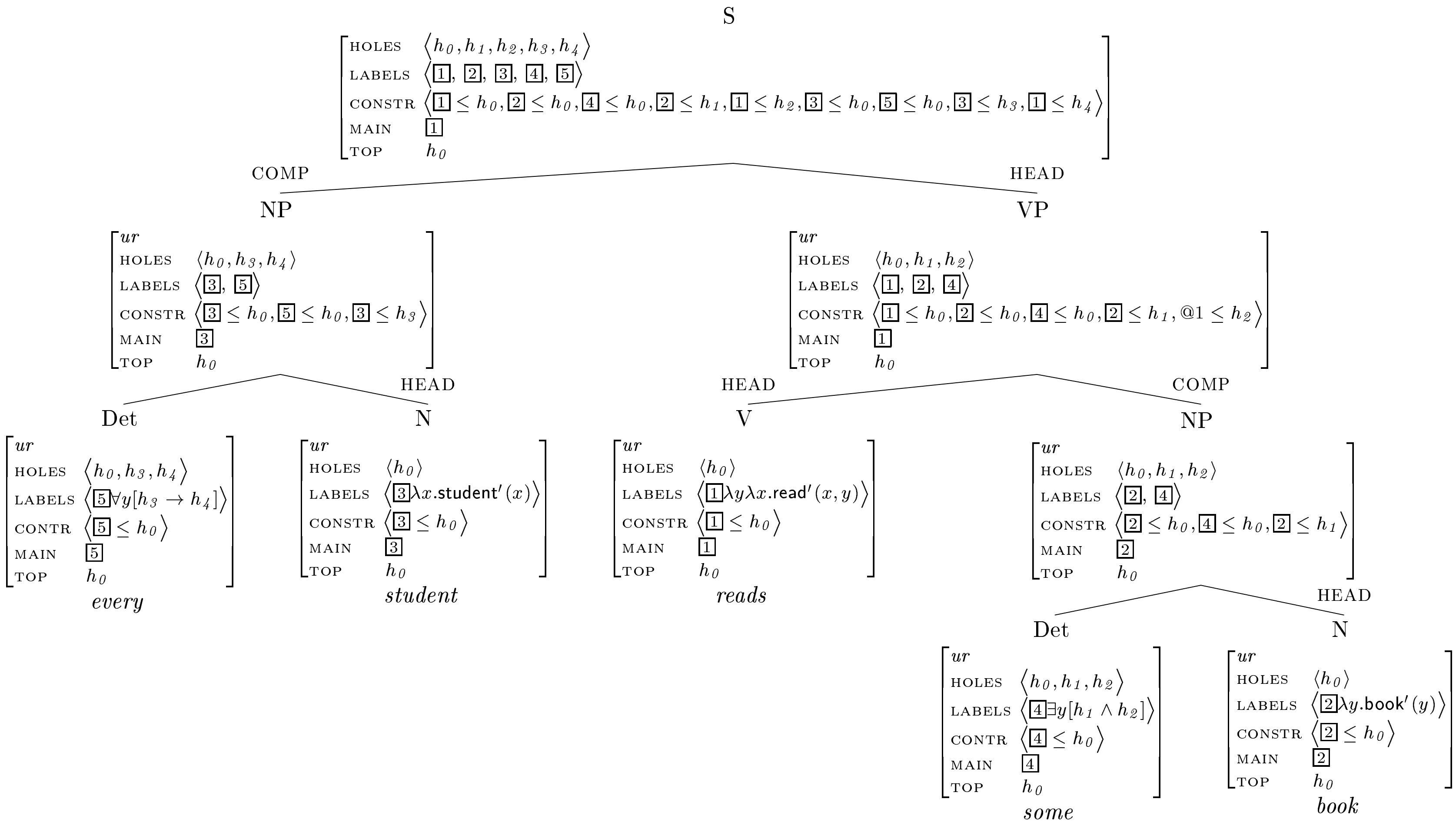


Figure 1: The analysis of the sentence *Every student reads some book.*:

Example 3: Positive Polarity Items A Positive Polarity Item may not be in the scope of negation (Ladusaw, 1980; Linebarger, 1980; Zwarts, 1981, ...):

(12) a. Peter already left.

b. * Peter didn't already leave.

Example (12b) is only well-formed under a meta-linguistic negation interpretation. If meta-linguistic *n't* is treated as a distinct lexical element the ungrammaticality of (12b) cannot be accounted for.

4.4 Technical Difficulties

- What kind of constraints are necessary? In Bos (1996) only constraints of the kind *"is subterm of/is in the scope of"* are possible. In Egg (1998) there are constraints of the forms *"is possibly in the immediate scope of"* and *"cannot possibly be in the immediate scope of"*. In Frank and Reyle (1995) there are even constraints of the form "$l_1 \leq l_2 \Rightarrow l_3 \leq l_4$".

- It is hard to express more complex constraints:

  (13) In a sentence S, if one in-situ interrogative pronoun takes scope over clause C then so does every clausemate in-situ interrogative pronoun.

  (14) a. Wer weiß, wem Maria wann was gegeben hat?
  who knows whom Maria when what given has

  b. $\lambda p.\exists x[p = \lambda w.[\mathsf{know}'_w(x, \lambda p.\exists y \exists z \exists t[\text{Maria gives } z \text{ to } y \text{ at } t]))]]$

  c. $\lambda p.\exists x \exists z \exists t[p = \lambda w.[\mathsf{know}'_w(x, \lambda p.\exists y[\text{Maria gives } z \text{ to } y \text{ at } t]))]]$

  d. $\$\ \lambda p.\exists x \exists z[p = \lambda w.[\mathsf{know}'_w(x, \lambda p.\exists y \exists t[\text{Maria gives } z \text{ to } y \text{ at } t]))]]$

  e. $\$\ \lambda p.\exists x \exists t[p = \lambda w.[\mathsf{know}'_w(x, \lambda p.\exists y \exists z[\text{Maria gives } z \text{ to } y \text{ at } t]))]]$

- Well-formedness constraints on underspecified representations are quite awkward to state such as the requirements

  - that the constraints should not lead to a cyclic plugging.
  - that every occurrence of a variable be properly bound.

- Depending on the semantic analysis, the two readings of (15) cannot be given a single underspecified representation.

  (15) Mary observed a man with a telescope.

- In Frank and Reyle (1995) and Egg (1998), the scope of a quantifier is underspecified but not its "reading", i.e., whether it is used distributively or collectively etc.

  (16) Wer hat jedem bei der Vorbereitung geholfen? (Pafel, 1998)
  who has everyone with the preparation helped
  'Who helped everyone with the preparation?'

  a. Detmar.

  b. Frank helped Manfred; Janina helped Frank; Manfred helped Sabine; ....

- It is unclear for which phenomena underspecification should be chosen.

4.5 Summary

Systems with underspecified denotation raise conceptual questions about the limits of grammar and have severe technical limitations.

5 Indirect Representation: Ty2U^P

5.1 A Sketch

We can extend the appropriateness conditions of the sort *ur* to contain also a **plugging**.

(17) a. *undersp.-repr*

HOLES	*list(hole)*
LABELS	*list(label)*
CONSTR(AINTS)	*list(constraint)*
PLUGGING	*list(plug)*
MAIN	*label*
TOP	*hole*

b. *plug*

HOLE	*hole*
LABEL	*label*

In Ty2U^P the CONTENT value of a sentence contains a bijection between the elements in the HOLES and the LABELS list as one of its members.
Description of the CONTENT values:

(18) a. The ∀∃-reading:

$$\begin{bmatrix} \text{HOLES} & \langle h_0, h_1, h_2, h_3, h_4 \rangle \\ \text{LABELS} & \langle \boxed{1}, \boxed{2}, \boxed{3}, \boxed{4}, \boxed{5} \rangle \\ \text{CONSTR} & \langle \boxed{1} \leq h_0, \boxed{2} \leq h_0, \boxed{4} \leq h_0, \boxed{2} \leq h_1, \boxed{1} \leq h_2, \boxed{3} \leq h_0, \boxed{5} \leq h_0, \boxed{3} \leq h_3, \boxed{1} \leq h_4 \rangle \\ \text{PLUG} & \langle h_0 = \boxed{5}, h_1 = \boxed{2}, h_2 = \boxed{1}, h_3 = \boxed{3}, h_4 = \boxed{4} \rangle \\ \text{MAIN} & \boxed{1} \\ \text{TOP} & h_0 \end{bmatrix}$$

b. The ∃∀-reading:

$$\begin{bmatrix} \text{HOLES} & \langle h_0, h_1, h_2, h_3, h_4 \rangle \\ \text{LABELS} & \langle \boxed{1}, \boxed{2}, \boxed{3}, \boxed{4}, \boxed{5} \rangle \\ \text{CONSTR} & \langle \boxed{1} \leq h_0, \boxed{2} \leq h_0, \boxed{4} \leq h_0, \boxed{2} \leq h_1, \boxed{1} \leq h_2, \boxed{3} \leq h_0, \boxed{5} \leq h_0, \boxed{3} \leq h_3, \boxed{1} \leq h_4 \rangle \\ \text{PLUG} & \langle h_0 = \boxed{3}, h_1 = \boxed{2}, h_2 = \boxed{5}, h_3 = \boxed{4}, h_4 = \boxed{1} \rangle \\ \text{MAIN} & \boxed{1} \\ \text{TOP} & h_0 \end{bmatrix}$$

5.2 Summary

- The empirical problems of Ty2U disappear.
- The technical problems remain.
- The effect of having a single semantic representation for ambiguous sentences is gone.

6 Fully Specified Denotation, Direct and Continuous Representation: LF-Ty2

6.1 A Sketch

LF-Ty2 is based on the flexible type shifting system of Hendriks (1993) (see also Dekker (1993), Bouma (1994)):

- there is a basic translation for every word
- type shifting rules can freely apply to the translation of words
- the logical form of a phrase is the (intensional) functional application of the logical forms of its daughters.

Basic translations:

Figure 2: The ∀∃ reading of the sentence *Every student reads some book*:

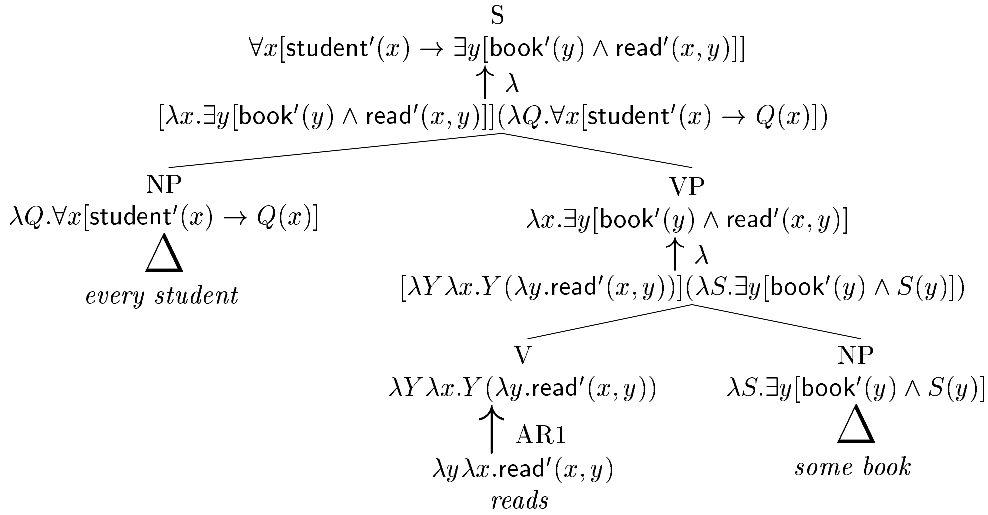
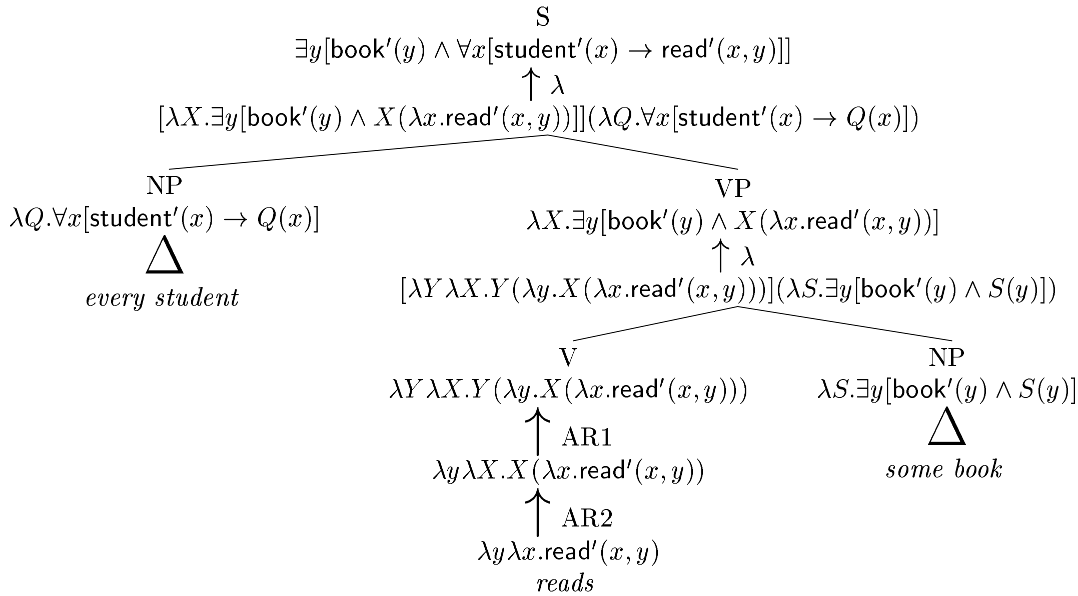


Figure 3: The ∃∀ reading of the sentence *Every student reads some book*:



(19) a. *read* $\rightsquigarrow \lambda y \lambda x.\mathsf{read}'(x, y)$

b. *book* $\rightsquigarrow \lambda y.\mathsf{book}'(y)$

c. *student* $\rightsquigarrow \lambda y.\mathsf{student}'(y)$

d. *some* $\rightsquigarrow \lambda P \lambda Q.\exists y[P(x) \wedge Q(x)]$

e. *every* $\rightsquigarrow \lambda P \lambda Q.\forall y[P(y) \rightarrow Q(y)]$

Type shifting rule:

(20) Argument Raising:

$$\lambda x_1 \ldots \lambda x_i \ldots \lambda x_n.\phi \longrightarrow_{AR_i} \lambda x_1 \ldots \lambda X_i \ldots \lambda x_n.X_i(\lambda x_i.\phi)$$

7 Discontinuous Representation: LRS

7.1 Introduction: Comparison of LF-Ty2 with LRS

- LF-Ty2 is closer to standard techniques in semantics.
- but the discontinuous representation in LRS allows us
  - to avoid complicated mechanism for combinatorial semantics such as λ conversion or type shifting,
  - to use identities in combinatorial semantics.

7.2 A Sketch

(21) The sort *lrs*

$$\begin{array}{lll} \textit{lrs} & \textsc{top} & \textit{me} \\ & \textsc{main} & \textit{me} \\ & \textsc{parts} & \textit{list(me)} \end{array}$$

(22) Every student reads some book
$\forall x[\mathsf{student}'(x) \rightarrow \exists y[\mathsf{book}'(y) \wedge \mathsf{read}'(x,y)]]$
$\exists y[\mathsf{book}'(y) \wedge \forall x[\mathsf{student}'(x) \rightarrow \mathsf{read}'(x,y)]]$

Relevant parts of the lexical entries:

(23) a. *read*: $\begin{bmatrix} \textit{lrs} & \\ \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{1}\ (\mathsf{read}'y)x \\ \textsc{parts} & \left\langle x, y, \boxed{1}, \boxed{1a}\mathsf{read}'y, \boxed{1b}\mathsf{read}' \right\rangle \end{bmatrix}$

b. *book* : $\begin{bmatrix} \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{2}\mathsf{book}'(y) \\ \textsc{parts} & \left\langle y, \boxed{2}, \boxed{2a}\mathsf{book}' \right\rangle \end{bmatrix}$

c. *student*: $\begin{bmatrix} \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{3}\mathsf{student}'(x) \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{student}' \right\rangle \end{bmatrix}$

d. *some*: $\begin{bmatrix} \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{4}\exists y[\alpha \wedge \beta] \\ \textsc{parts} & \left\langle y, \boxed{4}, \boxed{4a}\ [\alpha \wedge \beta] \right\rangle \end{bmatrix}$

e. *every*: $\begin{bmatrix} \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{5}\forall x[\gamma \rightarrow \delta] \\ \textsc{parts} & \left\langle x, \boxed{5}, \boxed{5a}\ [\gamma \rightarrow \delta] \right\rangle \end{bmatrix}$

(24) $\begin{bmatrix} \textit{lrs} & \\ \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{5} \begin{bmatrix} \textit{universal} & \\ \textsc{var} & x \\ \textsc{scope} & \boxed{5a} \begin{bmatrix} \textit{implication} & \\ \textsc{arg1} & \gamma\ \textit{me} \\ \textsc{arg2} & \delta\ \textit{me} \end{bmatrix} \end{bmatrix} \\ \textsc{parts} & \left\langle \boxed{5}, \boxed{5a}, x \right\rangle \end{bmatrix}$

Combinatorial Semantics:
We impose two well-formedness conditions on *lrs*:

(25) The MAIN PRINCIPLE (MP):
In each *lrs*, the MAIN value is an element of the PARTS list and a component of the TOP value.

(26) The Top Principle (TP):

1. In every phrase, the TOP value of the non-head daughter is an element of its PARTS list.
2. In every clause, the TOP value is the largest term of the PARTS list that consists exactly of the MAIN value's components and elements of the PARTS list.
3. In every utterance, every subterm of the TOP value of the utterance is an element of its PARTS list, and every element of the utterance's PARTS list is a subterm of the TOP value.

(27) Semantics Principle

In each *headed-phrase*,

1. the TOP value of the head and the mother are identical,
2. the MAIN value of the head and the mother are identical,[1]
3. the PARTS value contains exactly all elements of the PARTS values of the daughters,
4. the following conditions hold:
   (a) if the nonhead is a quantifier then its TOP value is of the form $Qx[\rho \circ \nu]$[2], the MAIN value of the head is a component of ρ, and the TOP values of both daughters are identical,
   (b) if the non-head is a quantified NP with a TOP value of the form $Qx[\rho \circ \nu]$, then the MAIN value of the head is a component of ν,
   (c) in a *head-marker-phrase*, the TOP value of the non-head is identical to the TOP value of the mother.
   (d) in a *head-adjunct-phrase*, the TOP value of the non-head is a component of the TOP value of the head, and
      i. if the non-head is an intersective modifier, then its TOP value is of the form $\alpha \wedge \beta$ and the MAIN value of the head is a component of β.
      ii. if the nonhead is a non-intersective modifier, then it is of the form $\alpha(\beta)$ and the MAIN value of the head is a component of β.

7.3 Case Study 1: Negative Concord in Polish

7.3.1 Data

N-Words are inherently negative:

(28) a. Kogo widziałeś? Nikogo.
Who have you seen? Nobody.GEN/ACC.

b. Ile przeczytałeś książek?
How many books have you read?

Żadnej./ Żadną.
None.GEN./ None.ACC.

(29) Chcę poślubić albo Piotra, albo nikogo.
I will marry either Piotr or nobody

(30) Kocham ją jak [żadną inną].
I love her.ACC as [no other].ACC

? Kocham ją jak [żadnej innej].
I love her.ACC as [no other].GEN

'I love her more than (I love) any other (girl).'

[1] We take the noun to be the head of a quantified NP.

[2] $Qx[\rho \circ \nu]$ is shorthand for the description $\begin{bmatrix} \textit{quantifier} & \\ \text{VAR} & \textit{var} \\ \text{SCOPE} & \begin{bmatrix} \textit{l-const} & \\ \text{ARG1} & \rho \\ \text{ARG2} & \nu \end{bmatrix} \end{bmatrix}$.

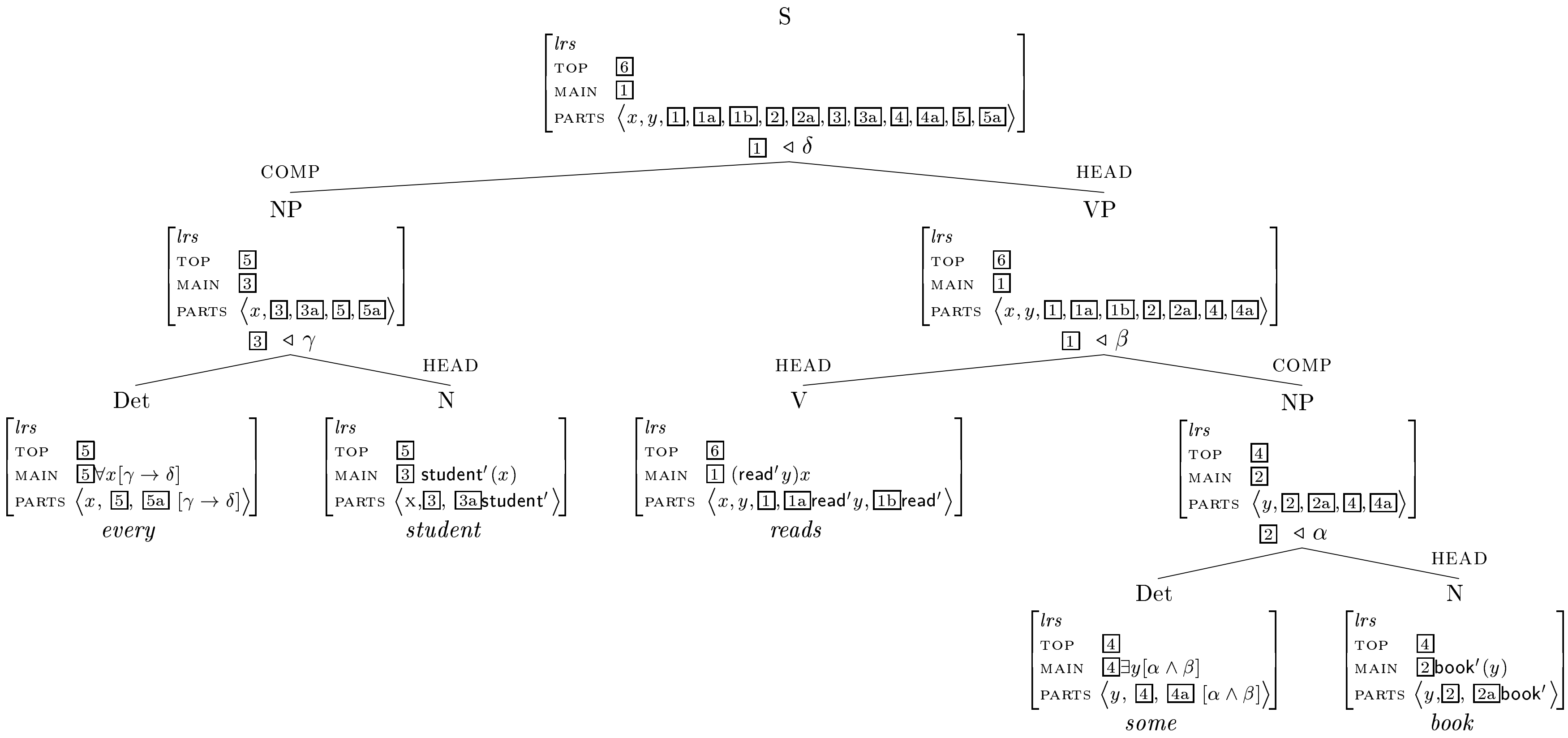


Figure 4: The LRS analysis of the sentence *Every student reads some book.*:

Non-negative n-words?

- *Nie* is obligatory in verbal contexts:

(31) Janek *(nie) pomaga nikomu.
Janek NM helped nobody
'Janek didn't help anybody.'
$ 'Janek didn't help nobody.'

- More than one n-word can occur, without there being a DN reading

(32) Nikt *(nie) pomaga nikomu.
Nobody NM helped nobody
'Nobody helped anybody.'

- Semantic material can intervene between the negation and the scope of the n-word:

(33) a. Janek nie szuka żadnego jednorożca.
Janek NM seeks no unicorn

b. Janek nie może nic czytać.
Janek NM can nothing read
'Janek is not allowed to read anything.'

- N-words occur in other contexts:

(34) Zaczął bez czekania na nikogo.
he-started without waiting for nobody
'He started without waiting for anybody.'

...but not in:

(35) * Widziałeś nikogo?
you-saw nobody
$ 'Did you see anybody?'

...but!

1. In all the grammatical examples we can postulate the presence of a negation at the logical form.
2. Polish n-words are not NPIs since they do not occur in the same envirionments as NPIs (only negativ contexts).

Conclusion There EXISTS evidence for the inherently negative character of Polish n-words.
There is NO compelling evidence for an inherently non-negative character.

7.3.2 Analysis

Description of the word *nie przyszedł* (*NM came*):

(36)
$$\left[\begin{array}{ll} \textit{word} & \\ \text{PHON} & \langle \textit{nie przyszedł} \rangle \\ \text{SYNS LOC CONT} & \left[\begin{array}{ll} \textit{lrs} & \\ \text{TOP} & \textit{me} \\ \text{MAIN} & \boxed{1}\ \mathsf{come}'(x) \\ \text{PARTS} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}', \boxed{2}\neg\alpha, \right\rangle \end{array}\right] \end{array}\right]$$
$\& \ \boxed{1} \triangleleft \alpha$

Relevant parts of the lexical entry of *nikt* (*nobody*):

(37)
$$\begin{bmatrix} \textit{word} & \\ \textsc{phon} & \langle \textit{nikt} \rangle \\ \textsc{syns loc cont} & \begin{bmatrix} \textit{lrs} & \\ \textsc{top} & \boxed{5}\ \exists x[\gamma \wedge \delta] \\ \textsc{main} & \boxed{3}\ \mathsf{human}'(x) \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{human}', \boxed{4}\neg\beta, \boxed{5}, \boxed{5a}[\gamma \wedge \delta] \right\rangle \end{bmatrix} \end{bmatrix}$$
$$\& \ \boxed{5} \lhd \beta$$
$$\& \ \boxed{3} \lhd \gamma$$

The analysis of *Nikt nie przyszedł* (*Nobody came*):

(38)
$$\begin{bmatrix} \textsc{top} & \boxed{6} \\ \textsc{main} & \boxed{1} \\ \textsc{parts} & \left\langle x, x, \boxed{1}, \boxed{1a}, \boxed{2}, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{bmatrix}$$

Nikt
$$\begin{bmatrix} \textsc{top} & \boxed{5} \\ \textsc{main} & \boxed{3} \\ \textsc{parts} & \left\langle x, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{bmatrix}$$

nie przyszedł
$$\begin{bmatrix} \textsc{top} & \boxed{6} \\ \textsc{main} & \boxed{1} \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}, \boxed{2} \right\rangle \end{bmatrix}$$

$$\& \ \boxed{1} \lhd \alpha$$
$$\& \ \boxed{5} \lhd \beta$$
$$\& \ \boxed{3} \lhd \gamma$$
$$\& \ \boxed{1} \lhd \delta$$

The following TOP values are possible:

(39)
a. $\neg\neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{4} \lhd \boxed{2} = \boxed{6})$ $= \exists x[\mathsf{come}'(x)]$
b. $\neg\exists x \neg[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{2} \lhd \boxed{4} = \boxed{6})$ $= \forall x[\mathsf{come}'(x)]$
c. $\neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)]$ $(\boxed{2} = \boxed{4} = \boxed{6})$

As only the third reading is available in Polish, we introduce the following, language-specific constraint:

The Negation Complexity Constraint:

(40) The NEGATION COMPLEXITY CONSTRAINT

For each sign, there may be at most one negation that is a component of the TOP value and has the MAIN value as its component.

(41) Poślubię albo tę dziewczynę z Poznania, albo żadnej dziewczyny z żadnego miasta.
I will marry either [this girl].ACC from Poznan or [no girl].GEN from no city.

'I will either marry this girl from Poznan or no girl from any city.'

(42) Tomek nie może nie znać Marii.
Tomek NM may NM know Maria

'It is not the case that it is possible that Tomek does not know Maria.'

The Neg Criterion:

(43) The NEG CRITERION:

For every verb, if there is a negation in the TOP value of the verb that has scope over the verb's MAIN value, then that negation must be an element of the verb's PARTS list.

(44) a. * Nikt przyszedł.
Nobody came

b. Relevant parts of the lexical entry of *przyszedł* (*came*):

$$\begin{bmatrix} \textit{word} & \\ \textsc{phon} & \langle \textit{przyszedł} \rangle \\ \textsc{syns loc cont} & \begin{bmatrix} \textit{lrs} & \\ \textsc{top} & \textit{me} \\ \textsc{main} & \boxed{1}\mathsf{come}'(x) \\ \textsc{parts} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}' \right\rangle \end{bmatrix} \end{bmatrix}$$

c.

$$\begin{bmatrix} \text{TOP} & \boxed{4}\ \neg\exists x[\mathsf{human}'(x) \wedge \mathsf{come}'(x)] \\ \text{MAIN} & \boxed{1}\ \mathsf{come}'(x) \\ \text{PARTS} & \left\langle x, \boxed{1}, \boxed{1a}, \boxed{3}, \boxed{3a}, \boxed{4}, \boxed{5}, \boxed{5a} \right\rangle \end{bmatrix}$$

Nikt

$$\begin{bmatrix} \text{TOP} & \boxed{5}\ \exists x[\gamma \wedge \delta] \\ \text{MAIN} & \boxed{3}\ \mathsf{human}'(x) \\ \text{PARTS} & \left\langle x, \boxed{3}, \boxed{3a}\mathsf{human}', \boxed{4}\neg\beta, \boxed{5}, \boxed{5a}[\gamma \wedge \delta] \right\rangle \end{bmatrix}$$

przyszedł

$$\begin{bmatrix} \text{TOP} & \boxed{4} \\ \text{MAIN} & \boxed{1}\ \mathsf{come}'(x) \\ \text{PARTS} & \left\langle x, \boxed{1}, \boxed{1a}\mathsf{come}' \right\rangle \end{bmatrix}$$

$\&\ \boxed{5} \lhd \beta$
$\&\ \boxed{3} \lhd \gamma$
$\&\ \boxed{1} \lhd \delta$

7.3.3 Opaque cases

The lexical entry for *nikt* in (37) was very simplistic. To account for the data with intensional and modal verbs, we must include a treatment of intensionality. We follow the Montagovian analysis of Hendriks (1993), but use Ty2 just as in Groenendijk and Stokhof (1982), i.e., we write @ for the variable $v_{s,0}$, and Montague's $\hat{}\phi$ becomes $\lambda @.\phi$ (see Gallin (1975))

(45) a. Add to (37):

- intensionality: $\mathsf{human}'_{@}(x_{@})$
- the following restriction: if there is an operator in δ in whose scope there is a free occurrence of x, then this operator can only be an existential.

b. Relevant parts of the lexical entry of *nikt* (*nobody*):

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{nikt} \rangle \\ \text{SYNS LOC CONT} & \begin{bmatrix} \textit{lrs} & \\ \text{TOP} & \boxed{5}\ \exists x[\gamma \wedge \delta] \\ \text{MAIN} & \boxed{3}\ \mathsf{human}'_{@}(x_{@}) \\ \text{PARTS} & \left\langle @, x, x_{@}, \boxed{3}, \boxed{3a}\mathsf{human}'_{@}, \boxed{3b}\mathsf{human}', \boxed{4}\neg\beta, \boxed{5}, \boxed{5a}[\gamma \wedge \delta] \right\rangle \end{bmatrix} \end{bmatrix}$$

$\&\ \boxed{5} \lhd \beta$
$\&\ \boxed{3} \lhd \gamma$
$\&\ \mathbf{A}\boxed{7} \left(\left(\boxed{7}\left[\text{VAR}\ \textit{variable}\right] \ \&\ \boxed{7} \lhd \delta \ \&\ \texttt{is-free}(x, \boxed{7}) \right) \Rightarrow \boxed{7}\left[\textit{existential}\right] \right)$

This accounts for the opaque cases:

(46) a. Janek nie szuka żadnego jednorożca.
Janek NM seeks no unicorn

$\lambda @.\neg\mathsf{seek}'_{@}(j, \lambda @ \lambda P.\exists x[\mathsf{unicorn}'_{@}(x_{@}) \wedge P_{@}(x)])$

b. Description of the word *nie szuka* (*NM seeks*):

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{nie szuka} \rangle \\ \text{SYNS LOC CONT} & \begin{bmatrix} \textit{lrs} & \\ \text{TOP} & \textit{me} \\ \text{MAIN} & \boxed{8}\ P_{@}(y) \\ \text{PARTS} & \langle @, x, y, P, x_{@}, \\ & \boxed{1}\mathsf{seek}'_{@}(x, \lambda @ \lambda P.\epsilon), \boxed{1a}\mathsf{seek}'_{@}(\lambda @ \lambda P.\epsilon), \boxed{1b}\mathsf{seek}'_{@}, \boxed{1c}\mathsf{seek}', \\ & \boxed{0}\lambda @.\zeta, \boxed{2}\neg\alpha, \boxed{7}\lambda @ \lambda P.\epsilon, \boxed{7a}\lambda P.\epsilon, \boxed{8}P_{@}(y), \boxed{8a}P_{@} \rangle \end{bmatrix} \end{bmatrix}$$

$\&\ \boxed{1} \lhd \alpha$ (seek' is in the scope of $\neg$)
$\&\ \boxed{2} \lhd \zeta$ ($\neg$ is in the scope of the top $\lambda @$)
$\&\ \boxed{8} \lhd \epsilon$ ($P_{@}(y)$ is in the scope of seek')

For the modal verbs, we assume a syntactic analysis along the lines of Przepiórkowski (1999), i.e., modals are "argument raisers" (Hinrichs and Nakazawa, 1994), but raising does not extend beyond a *nie*-prefixed verb. To get the word order right, we assume an order domain approach of the kind proposed for German (Reape, 1992; Kathol, 1995; Richter and Sailer, 1995; Richter, 1997) and for Slavonic (Penn, 1999).

(47) a. Janek nie może nic czytać.
Janek NM can nothing read

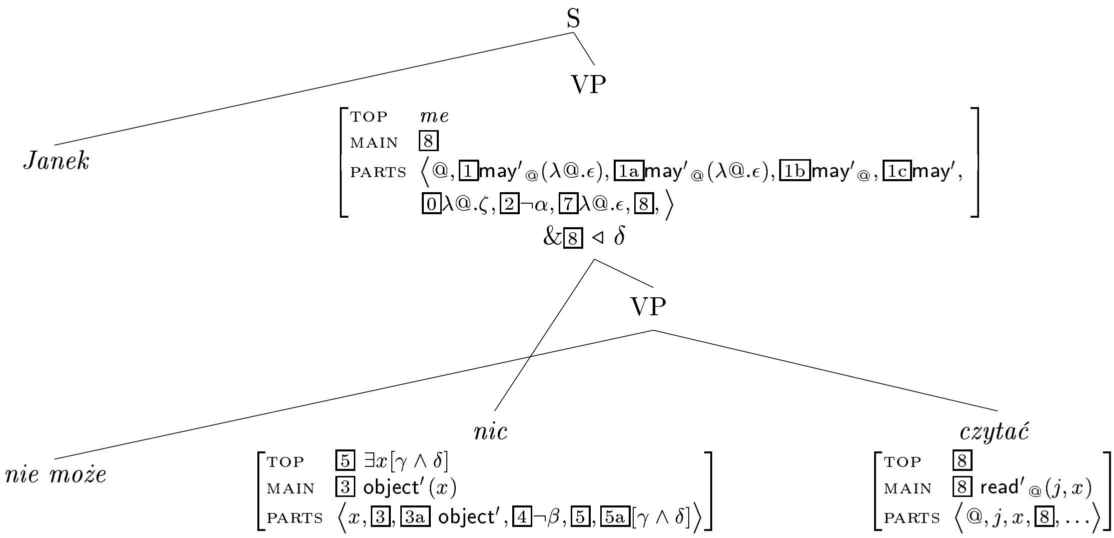
$\lambda @.\neg \mathsf{may}'_{@}(\lambda @.\exists x[\mathsf{object}'_{@}(x_{@}) \wedge \mathsf{read}'_{@}(j, x_{@})])$

b. Description of the word *nie może* (*NM can*):

$$\begin{bmatrix} \textit{word} & \\ \text{PHON} & \langle \textit{nie może} \rangle \\ \text{SYNS LOC} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{SUBCAT} & \boxed{9} \oplus \left\langle \begin{bmatrix} \text{SS L} & \begin{bmatrix} \text{CAT} & \begin{bmatrix} \text{HD} & \textit{verb} \\ \text{SBC} & \boxed{9} \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \text{TOP} & \boxed{8} \end{bmatrix} \end{bmatrix} \end{bmatrix} \right\rangle \end{bmatrix} \\ \text{CONT} & \begin{bmatrix} \textit{lrs} & \\ \text{TOP} & \textit{me} \\ \text{MAIN} & \boxed{8} \\ \text{PARTS} & \langle @, \boxed{1}\mathsf{may}'_{@}(\lambda @.\epsilon), \boxed{1a}\mathsf{may}'_{@}(\lambda @.\epsilon), \boxed{1b}\mathsf{may}'_{@}, \boxed{1c}\mathsf{may}', \\ & \boxed{0}\lambda @.\zeta, \boxed{2}\neg\alpha, \boxed{7}\lambda @.\epsilon, \boxed{8}, \rangle \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

$\& \boxed{1} \triangleleft \alpha$
$\& \boxed{2} \triangleleft \zeta$
$\& \boxed{8} \triangleleft \epsilon$

c. The analysis of (a):



7.3.4 Evaluation of the analysis

- Our analysis avoids mechanisms such as *negative absorption*:
  $\forall x_1 \neg \forall x_2 \ldots \neg \forall x_n \neg \phi \Longrightarrow \forall x_1 \forall x_2 \ldots \forall x_n \neg \phi$
- instead, it uses *identities*:
  - identities are the major analytical device of HPSG
  - identities arise wherever possible, so NC languages are predicted to be the unmarked case.
- The Negation Complexity Constraint and the Neg Criterion are adaptations of standard principles.
- An LF-Ty2 analysis of the same empirical domain is much more complex (Richter and Sailer, 1999b).

7.4 Case Study 2: Sentential Semantics in German

The account of Negative Concord by identities in the logical form is transferred to interrogative semantics in German in Richter and Sailer (2001a).

(48) a. Liest Peter das Buch?
reads Peter the book
'Does Peter read the book?'

b. Wer liest das Buch?
who reads the book

c. Ich frage mich, ob Peter das Buch liest.
I ask myself whether Peter the book reads
'I wonder whether Peter reads the book.'

d. Ich frage mich, wer das Buch liest.
I ask myself who the book reads

(49) a. * Hans liest welches Buch?
Peter reads which book
$\lambda p.\exists x[\mathsf{book}'_w(x) \wedge p = \lambda w.\mathsf{read}'_w(h, x)]$

b. Wer liest welches Buch?
who reads which book
$\lambda p.\exists x \exists y[\mathsf{book}'_w(y) \wedge p = \lambda w.\mathsf{read}'_w(x, y)]$

7.5 Summary

- LRS does not introduce an additional level of "underspecification" but makes use of the fact that
  - a sign contains its logical form as its component
  - one description can characterize many distinct objects
  - as these objects are terms, we have a natural place for "underspecification" in the grammar,
  - but this does not lead to an underspecification in the denotation nor to an indirect representation.
- the empirical and the technical problems of denotationally underspecified or indirect systems are avoided.

8 Perspectives

- Classification of existing semantic representation languages of HPSG with respect to Table 1
- Implementation: Development of an LRS module for ALE (joint work with Gerald Penn)
  Challenge: Finding an elegant way of specifying the semantics

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