

Knowledge Engineering for NLP

February 4, 2008

Software review, MRS

Overview

- Software review
- MRS: goals
- MRS: representations
- MRS: composition

Software review

- What are the various pieces of software we're using?

Software review

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 - emacs
 - make_item.pl
 - customization system
 - lkb
 - [incr tsdb()]
- What do they each do?

MRS Preface

- Most of today's lecture covers stuff that is already implemented in the Matrix.
- The goal of this presentation is to increase your understanding of what's already there, and how to have your code interact with it.
- In the near term, you'll need to be able to look at the semantic representations and understand them.
- In later labs, you'll also be working on compositionality.

Semantics: Overall strategy

- Represent all semantic distinctions which are syntactically (or morphologically) marked.
- Underspecify semantic distinctions which don't correspond to differences in form.
- (These can be 'spelled out' in post-processing.)
- Abstract away from non-semantic information (case, word order)
- Aim for consistency across languages (for purposes of downstream processing).
- Allow for semantic differences between languages.

Semantics: Scope

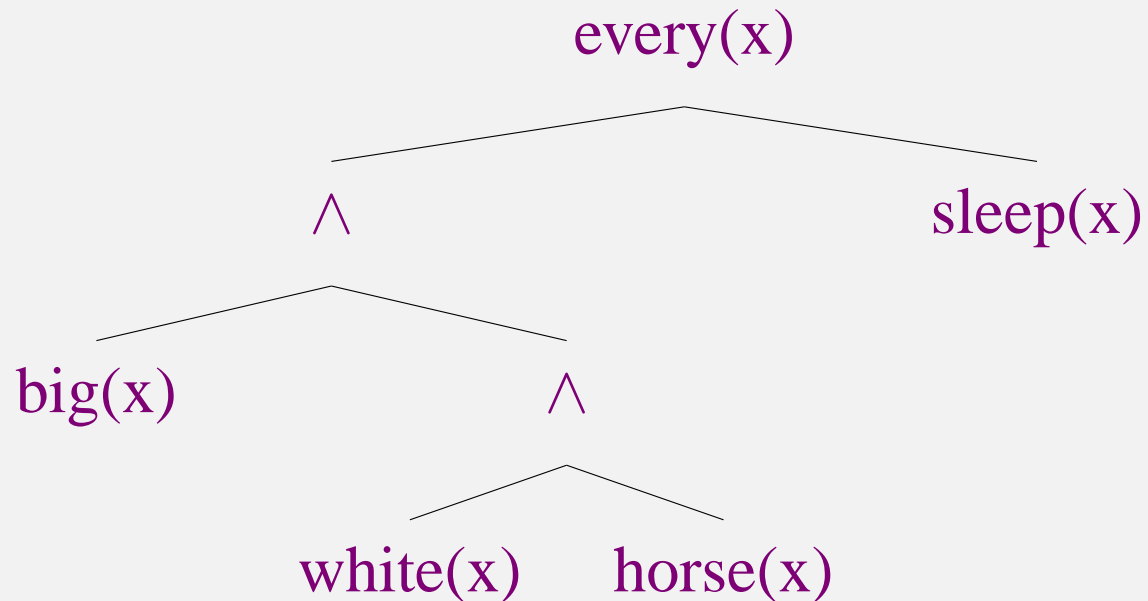
- Quantifiers (predicate logic or natural language) take three arguments:
 - A variable to bind
 - A restriction
 - A body
- Every dog sleeps: $\forall x \text{ dog}(x) \text{ sleep}(x)$
- When one quantifier appears within the restriction or body of another, we say the first has wider scope.

MRS: Goals

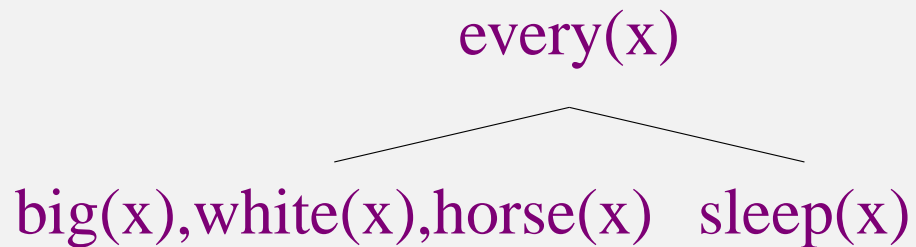
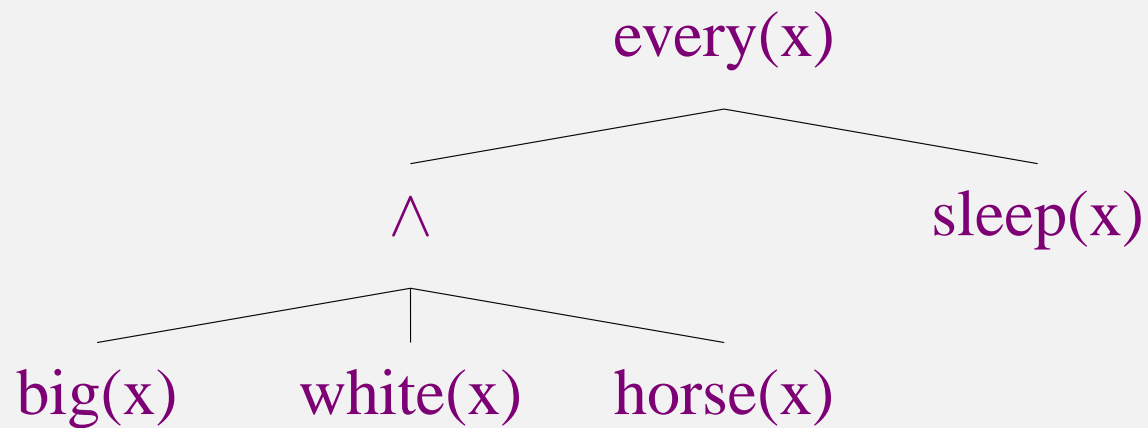
- Adequate representation of natural language semantics
- Grammatical compability
- Computational tractability
- Underspecifiability

Working towards MRS (1/4)

- Every big white horse sleeps.
- every (x , $\wedge(\text{big}(x), \wedge(\text{white}(x), \text{horse}(x)))$, $\text{sleep}(x)$)

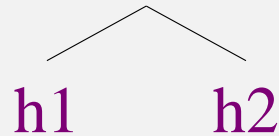


Working towards MRS (2/4)



Working towards MRS (3/4)

h0:every(x)



h1:big(x), h1:white(x), h1:horse(x)

h2:sleep(x)

- And finally:

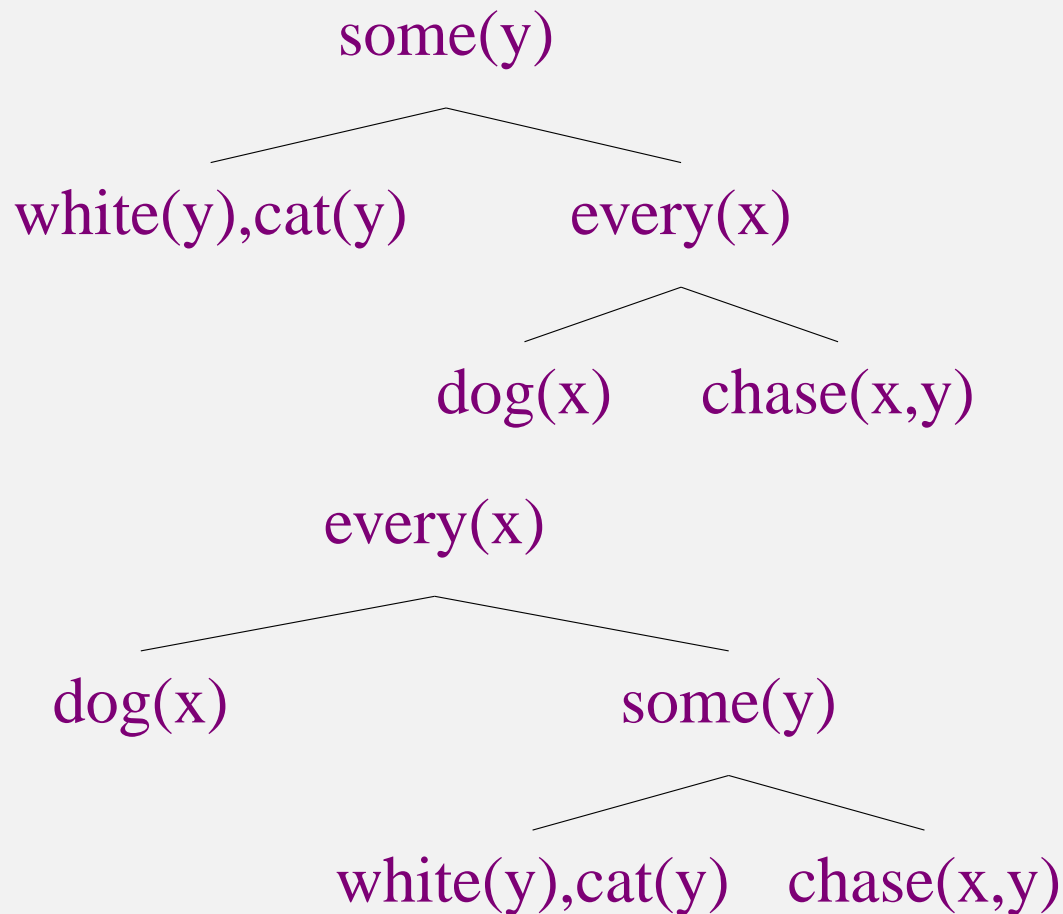
$h0:every(x, h1, h2), h1:big(x), h1:white(x),$
 $h1:horse(x), h2:sleep(x)$

Working towards MRS (4/4)

- This is a flat representation, which is a good start.
- Next we need to underspecify quantifier scope, and it's easier to see why with multiple quantifiers.
- At the same time, we want to be able to partially specify it, since this is required for adequate representations of NL semantics.

Underspecified quantifier scope (1/2)

- Every dog chases some white cat.



Underspecified quantifier scope (2/2)

- $h1:\text{every}(x, h3, h4), h3:\text{dog}(x), h7:\text{white}(y), h7:\text{cat}(y),$
 $h5:\text{some}(y, h7, h1), h4:\text{chase}(x, y)$
- $h1:\text{every}(x, h3, h5), h3:\text{dog}(x), h7:\text{white}(y), h7:\text{cat}(y),$
 $h5:\text{some}(y, h7, h4), h4:\text{chase}(x, y)$
- $h1:\text{every}(x, h3, hA), h3:\text{dog}(x), h7:\text{white}(y), h7:\text{cat}(y),$
 $h5:\text{some}(y, h7, hB), h4:\text{chase}(x, y)$

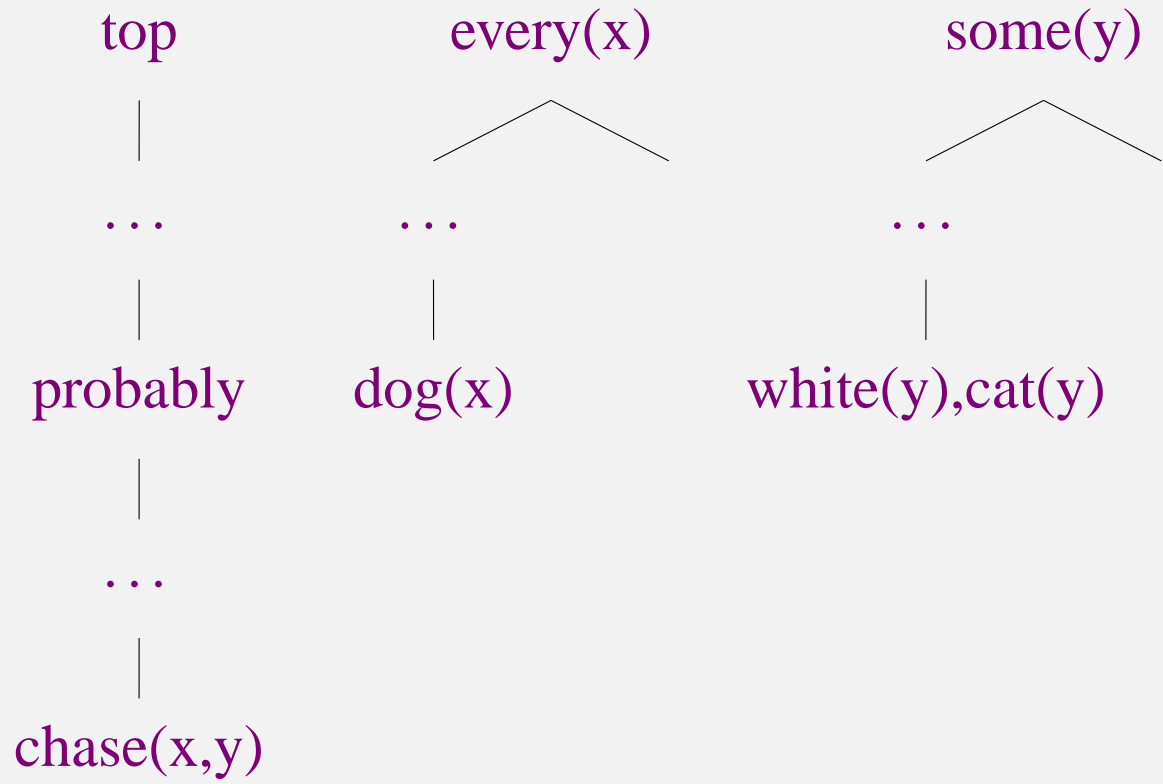
Partially constrained quantifier scope (1/5)

- For the BODY of quantifiers, we have no particular constraints to add.
- It turns out that the RESTRICTION needs to have partially unconstrained scope:
 - Every nephew of some famous politician runs.
 - $\text{every}(x, \text{some}(y, \text{famous}(y) \wedge \text{politician}(y)), \text{nephew}(x, y)) \text{run}(x)$
 - $\text{some}(y, \text{famous}(y) \wedge \text{politician}(y), \text{every}(x, \text{nephew}(x, y), \text{run}(x)))$

Partially constrained quantifier scope (2/5)

- Every nephew of some famous politician runs.
 - But not:
 - $\text{every}(x, \text{run}(x), \text{some}(y, \text{famous}(y) \wedge \text{politician}(y), \text{nephew}(x, y)))$
 - ‘Everyone who runs is a nephew of a famous politician.’

Partially constrained quantifier scope (4/5)



Partially constrained quantifier scope (5/5)

- $\langle h_0, \{h_2 : \text{every}(x, h_3, h_4), h_5 : \text{nephew}(x, y), h_6 : \text{some}(y, h_7, h_8), h_9 : \text{politician}(y), h_9 : \text{famous}(y), h_{10} : \text{run}(x)\}, \{h_1 =_q h_{10}, h_7 =_q h_9, h_3 =_q h_5\}\rangle$
- $\langle h_0, \{h_1 : \text{every}(x, h_2, h_3), h_4 : \text{dog}(x), h_5 : \text{probably}(h_6), h_7 : \text{chase}(x, y), h_8 : \text{some}(y, h_9, h_{10}), h_{11} : \text{white}(y), h_{11} : \text{cat}(y)\}, \{h_0 =_q h_5, h_w =_q h_4, h_6 =_q h_7, h_9 =_q h_{11}\}\rangle$

We've arrived at MRS!

- Flat structure
- Underspecification/partial specification of scope is possible

Linguistic questions

- How do we build MRS representations compositionally?
- Is it linguistically adequate to insist that no process suppress relations?
- Under what circumstances do NLs (partially) constrain scope?
- Is it linguistically adequate to give scopal elements (esp. quantifiers, but also scopal modifiers) center-stage?

MRS in feature structures

- RELS: List (diff-list) of relations
- HCONS: List (diff-list) of handle constraints
- HOOK: Collection of features ‘published’ for further composition: INDEX, LTOP, XARG
- ARGn: Roles within relations

Summary: Anatomy of an MRS

- An MRS consists of:
 - A top handle
 - A list of relations, each labeled by a handle
 - A list of handle constraints
- An (underspecified) MRS is well-formed iff the constraints can be resolved to form one or more trees (singly-rooted, connected, directed acyclic graphs).

Anatomy of a relation (1/2)

- A relation has:
 - A predicate (string or type)
 - A label (handle)
 - One or more arguments: ARG0-n (ARG0 canonically being the event or individual introduced by the relation)

Anatomy of a relation (2/2)

- The value of each ARG_n is either:
 - An index, canonically identified with the ARG₀ of another relation
 - A handle: identified with the label of another relation, the HARG of a handle constraint, or not identified with anything

Anatomy of a handle constraint

- Current sole handle constraint type: *qeq*
- ‘Equal modulo quantifiers’
- Features: HARG, LARG
- → Unless some quantifier scopes in between, the value of this ARGn is the same as the label of that relation.
- When the label of a relation is the value of an ARGn, this corresponds to a branch in an MRS tree.
- When the value of an ARGn is *qeq* the label of a relation, this corresponds to a ‘dotted’ branch – i.e., a dominance relation.

When else are handles identified?

- Relations with the same handle value share the same scope.
- Typically, we see this with intersective modifiers (adverbs, adjectives, PPs) which share their handles with their modifies.

Composition: Overview

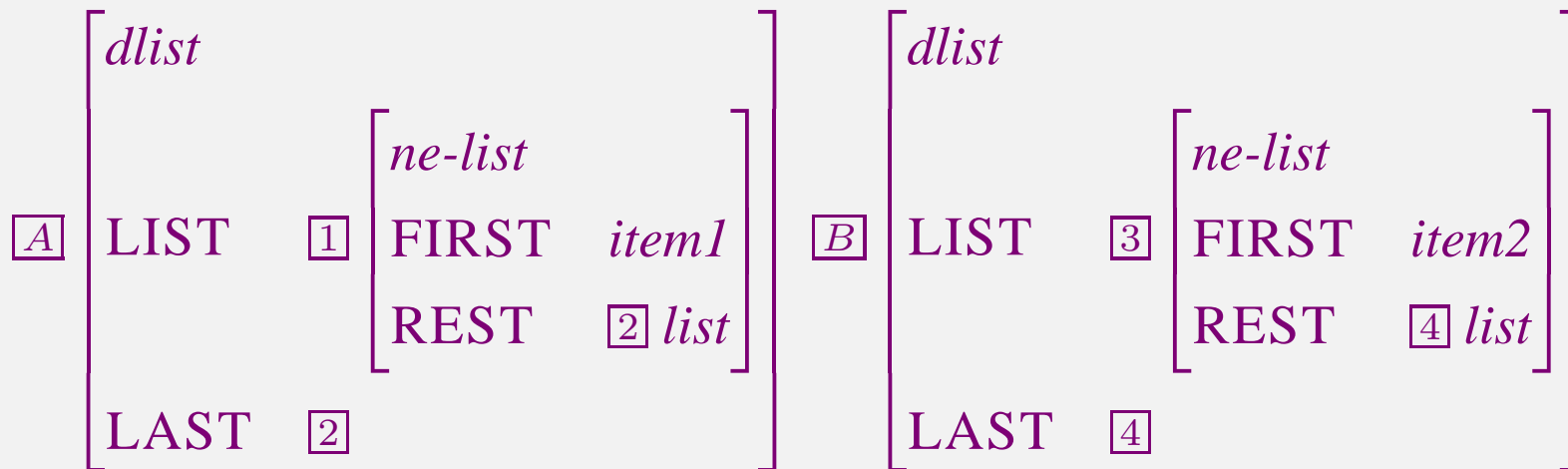
- RELS and HCONS on mother nodes
- HOOK, LKEYS
- ARGn \leftrightarrow indices
- ARGn \leftrightarrow handles
- LBL \leftrightarrow LBL
- Building qeqs

RELS and HCONS on mother nodes

- The RELS and HCONS value of the mother is the append of the values from the daughter(s) and the C-CONT of the mother.
- C-CONT is the ‘constructional content’: allows phrase structure rules to introduce relations.
- Examples?
- From a semantic point of view, the C-CONT is just another daughter.

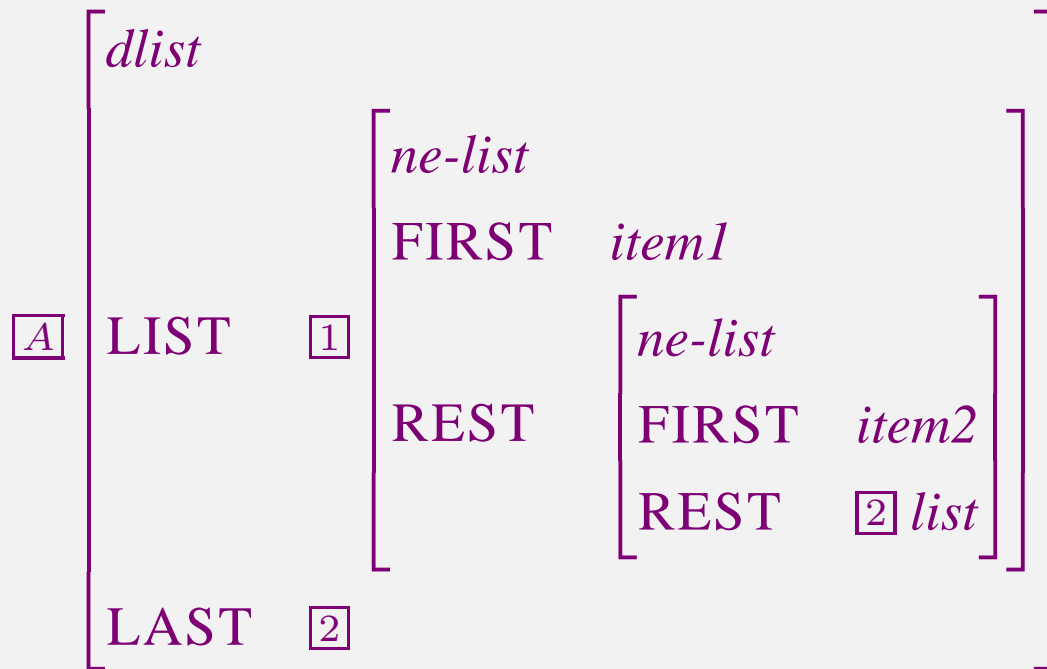
Appending lists with unification

- A *diff-list* embeds an open-ended list into a container structure providing a ‘pointer’ to the end of the ordinary list.



- To append : (i) unify the front of \boxed{B} (i.e. the value of its LIST feature) into the tail of \boxed{A} (its LAST value) and
- (ii) use the tail of difference list \boxed{B} as the new tail for the result of the concatenation.

Result of appending lists



Matrix type: dl-append

- **Not** for direct use in the grammar: this type is just meant as a reference.

```
dl-append := avm & [APPARG1 [LIST #first,  
                             LAST #between],  
                   APPARG2 [LIST #between,  
                             LAST #last],  
                   RESULT  [LIST #first,  
                             LAST #last]].
```

Diff-lists: practicalities

- Typically errors with diff-lists involve circularity and not direct unification failure.
- If the LKB complains about circular feature structures, check your difference lists.
- Don't try to constrain the length of a difference list.
- Unifying structures which include diff lists in an append relation can result in diff lists constrained to be empty.

Returning to our regularly scheduled programming...

- Why do we need diff-lists?
- Why do we need append?

Now what

- Phrase structure rules (and lexical rules) gather up RELS and HCONS from daughters.
- Phrase structure rules also (optionally) introduce further RELS and HCONS.
- How do we link the ARGn positions of the relations to the right things?
- How do we link the HARG/LARG of qeqs to the right things?

HOOK (1/2)

- The CONT.HOOK is the information that a given sign exposes for further composition.
- By hypothesis, this includes only:
 - INDEX (the individual or event denoted by the sign, linked to some ARG0)
 - LBL (the local top handle of the sign)
 - XARG (the external argument of the sign)

HOOK (2/2)

- The HOOK of a sign is identified its with the C-CONT.HOOK.
- The C-CONT.HOOK in turn is identified with the semantic head daughter, if there is one.
- Otherwise, the LBL, INDEX, and XARG inside C-CONT.HOOK need to be constrained appropriately.

LKEYS

- The feature LKEYS houses pointers to important relations on the RELS list, most notably LKEYS.KEYREL.
- Only appropriate for lexical items.
- Serves as a uniform place to state linking constraints.
- Linking constraints: equality between HOOK.INDEX or HOOK.LBL of arguments/modifiees and LKEYS.KEYREL.ARG_n.

ARGn ↔ *indices*

```
intransitive-lex-item := basic-one-arg-no-hcons &  
  [ ARG-ST < [ LOCAL.CONT.HOOK.INDEX ref-ind &  
              #ind ] >,  
    SYNSEM.LKEYS.KEYREL.ARG1 #ind ] .
```

```
intersective-mod-lex := no-hcons-lex-item &  
  [ SYNSEM [ LOCAL.CAT.HEAD.MOD  
            < [ ..INDEX #ind ] ] >,  
    LKEYS.KEYREL.ARG1 #ind ] ] .
```

ARGn \leftrightarrow *handles (1/2)*

```
clausal-second-arg-trans-lex-item := basic-two-arg &
[ ARG-ST < [ LOCAL.CONT.HOOK.INDEX ref-ind & #ind ],
  [ LOCAL.CONT.HOOK.LTOP #larg ] >,
  SYNSEM [ LOCAL.CONT.HCONS <! qeq &
    [ HARG #harg,
      LARG #larg ] !>,
  LKEYS.KEYREL [ ARG1 #ind,
    ARG2 #harg ] ] ] .
```

ARGn ↔ *handles* (2/2)

```
basic-determiner-lex := norm-hook-lex-item &
  [ SYNSEM [ LOCAL
    [ CAT [ HEAD det,
      VAL..HOOK [ INDEX #ind,
        LTOP #larg ] ],
    CONT [ HCONS <! qeq &
      [ HARG #harg,
        LARG #larg ] !>,
      RELS <! relation !> ] ],
    LKEYS.KEYREL quant-relation &
      [ ARG0 #ind,
        RSTR #harg ] ] ] .
```

$$LBL \leftrightarrow LBL$$

```
intersect-mod-phrase :=  
  head-mod-phrase-simple &  
  head-compositional &  
  [ HEAD-DTR.SYNSEM.LOCAL.CONT.HOOK.LTOP #hand ],  
    NON-HEAD-DTR.SYNSEM.LOCAL.CONT.HOOK.LTOP #hand
```

- The rule for intersective modifiers identifies the LTOP of the two daughters, and thus the LBL of the main relation introduced by each.
- The HOOK value of the whole thing comes from the syntactic head, thanks to the type *head-compositional*.

Scopal modifiers (1/2)

```
scopal-mod-phrase :=  
  head-mod-phrase-simple &  
  [ NON-HEAD-DTR.SYNSEM.LOCAL  
    [ CAT.HEAD.MOD < [ LOCAL scopal-mod ] >,  
      CONT.HOOK #hook ],  
    C-CONT [ HOOK #hook,  
             HCONS <! !> ] ] .
```

- No identification of LTOPs.
- Non-head (adjunct) daughter is the semantic head.

Scopal modifiers (2/2)

```
scopal-mod-lex := lex-item &
  [ SYNSEM [ LOCAL [
    CAT.HEAD.MOD < [ LOCAL scopal-mod &
                    [ ..LTOP #larg ] ] >,
    CONT.HCONS <! qeq &
                [ HARG #harg,
                  LARG #larg ] !> ],
    LKEYS.KEYREL.ARG1 #harg ]].
```

- Builds qeq between its ARG1 and the MOD's LTOP

Building qeqs

- Determiners
- Scopal adverbs
- Clausal complement verbs (and nouns, adjectives, adpositions...)

Summary

- Phrase structure rules:
 - ... gather up RELS and HCONS
 - ... potentially add further RELS and HCONS
 - ... unify elements on valence/mod lists with signs
 - ... pass up and/or modify HOOK information
- Lexical entries:
 - ... orchestrate the linking between valence/mod lists and the ARGn positions in the relations they contribute
 - ... expose certain information in the HOOK

Composition: Summary

- RELS and HCONS on mother nodes
- HOOK, LKEYS
- ARGn \leftrightarrow indices
- ARGn \leftrightarrow handles
- LBL \leftrightarrow LBL
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