Knowledge Engineering for NLP

January 26, 2009

Minimal Recursion Semantics

Overview

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

Software review

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

Software review

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

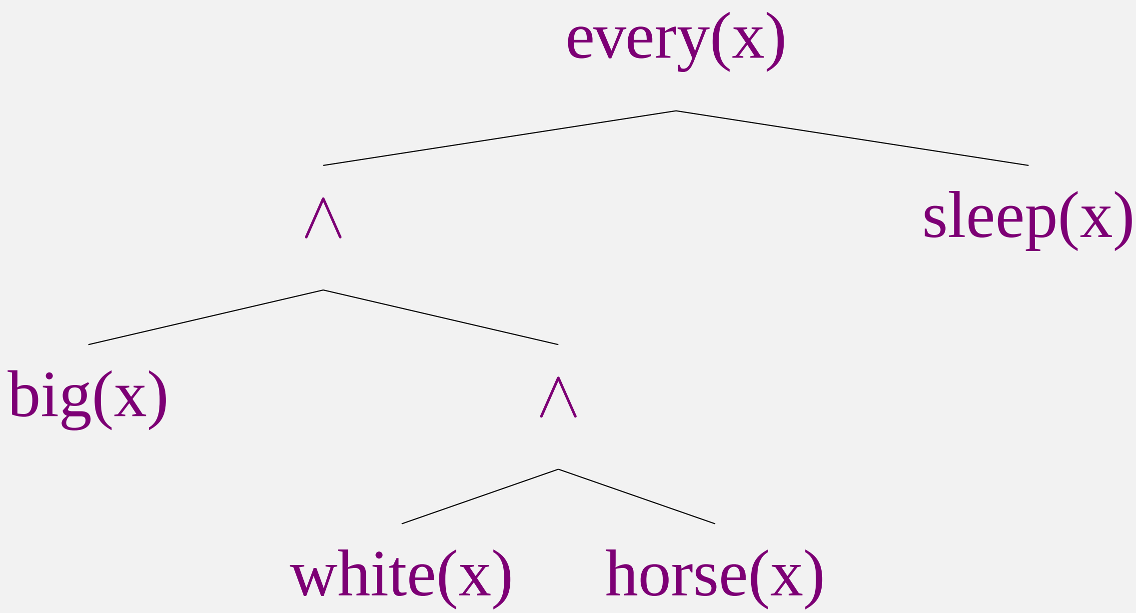
- Quantifiers (predicate logic or natural language) take three arguments:
  - A variable to bind
  - A restriction
  - A body
- Every dog sleeps: $\forall x\, dog(x) sleep(x)$
- When one quantifier appears within the restriction or body of another, we say the first has wider scope.

MRS: Goals

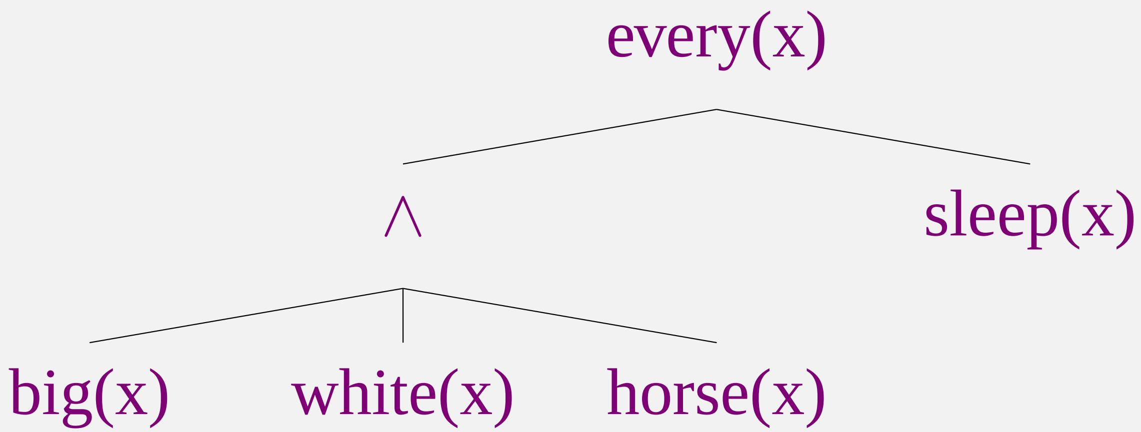
- Adequate representation of natural language semantics
- Grammatical compability
- Computational tractability
- Underspecifiability

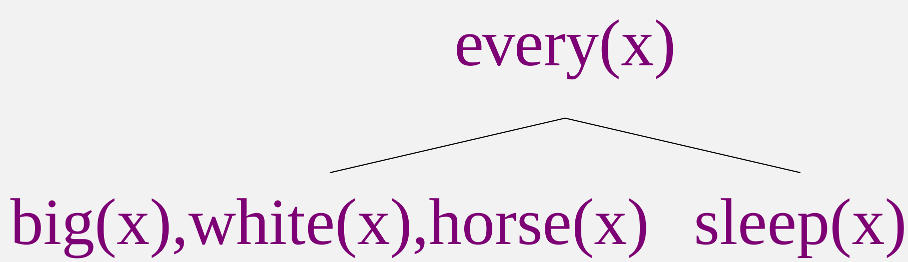
Working towards MRS (1/4)

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



Working towards MRS (2/4)





Working towards MRS (3/4)

h0:every(x)

h1 h2

h1:big(x), h1:white(x), h1:horse(x) h2:sleep(x)

- And finally:

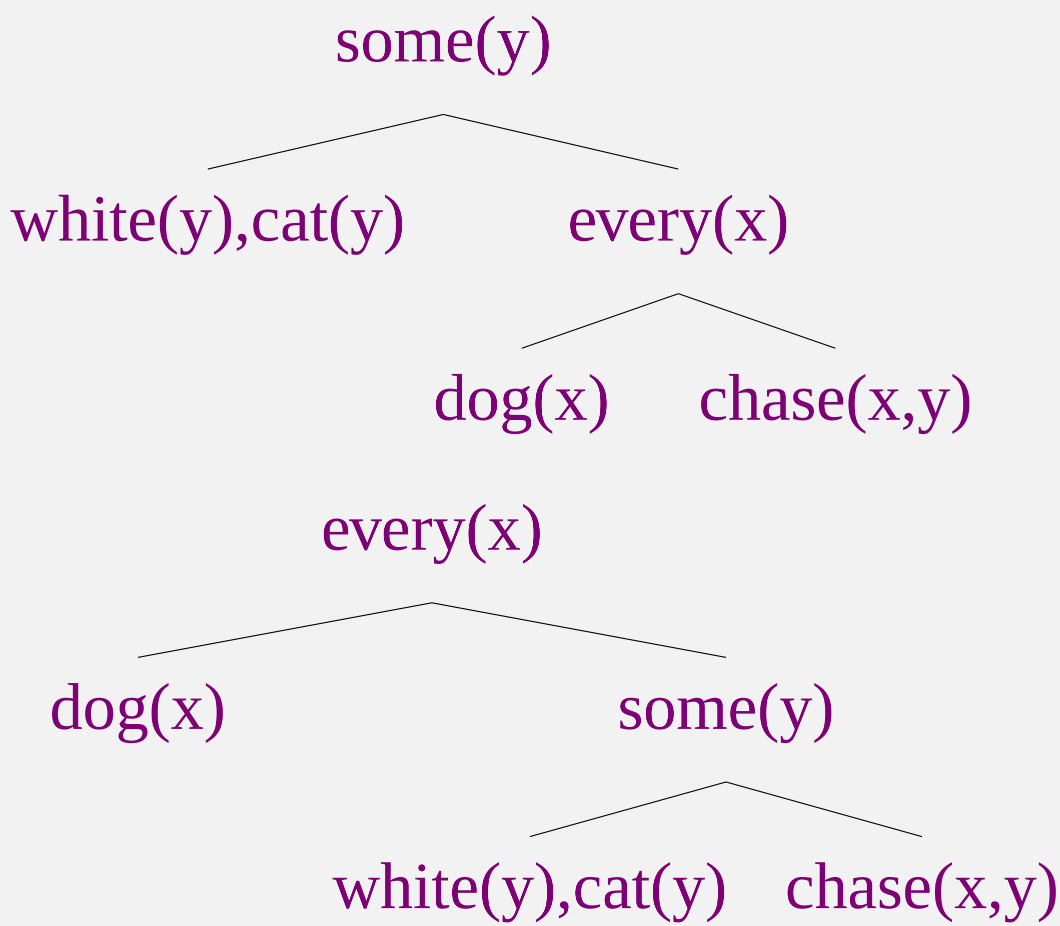
  $h0$:every(x, $h1$, $h2$), $h1$:big(x), $h1$:white(x), $h1$:horse(x), $h2$:sleep(x)

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)

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

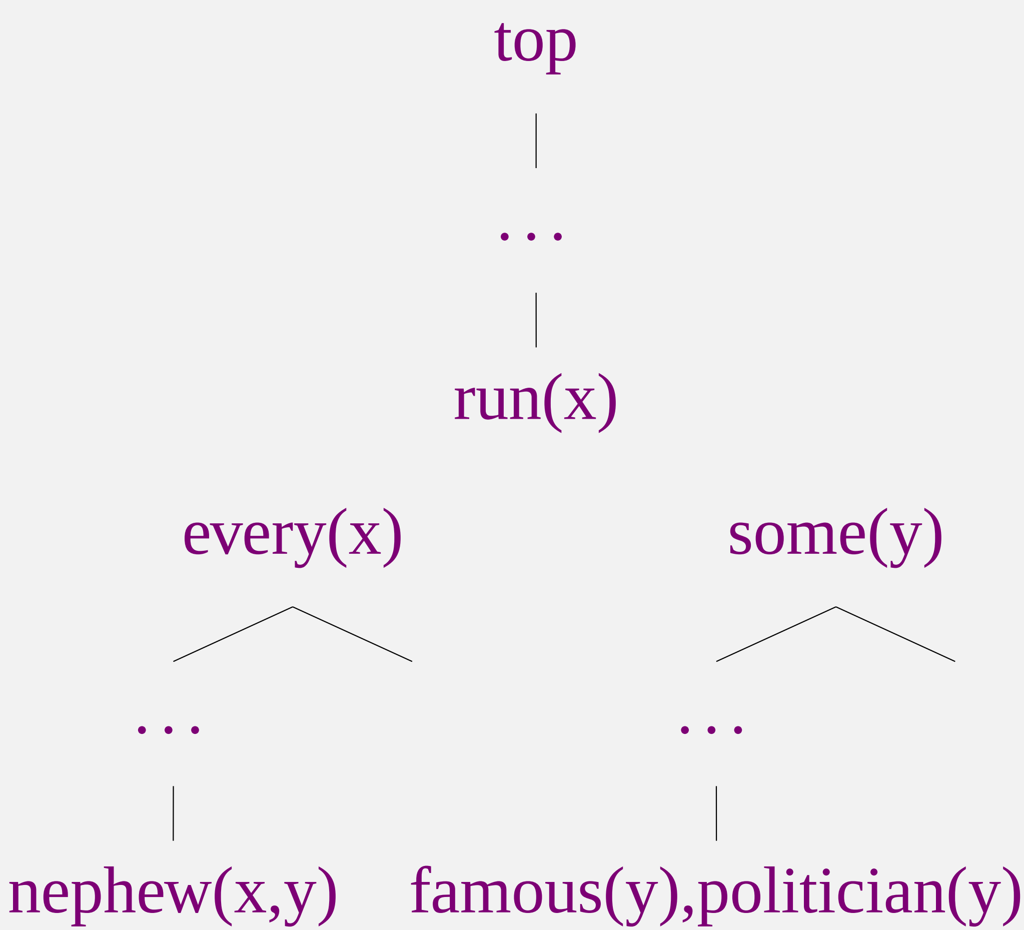
Partially constrained quantifier scope (1/5)

- For the BODY of quantifiers, we have no particular constraints to add.
- In turns out that the RESTRICTION needs to have partially underconstrained scope:
  - Every nephew of some famous politican runs.
  - every(x,some(y,famous(y) $\wedge$ politican(y), nephew(x,y)) run(x))
  - some(y,famous(y) $\wedge$ politican(y), every(x, newphew(x,y),run(x)))

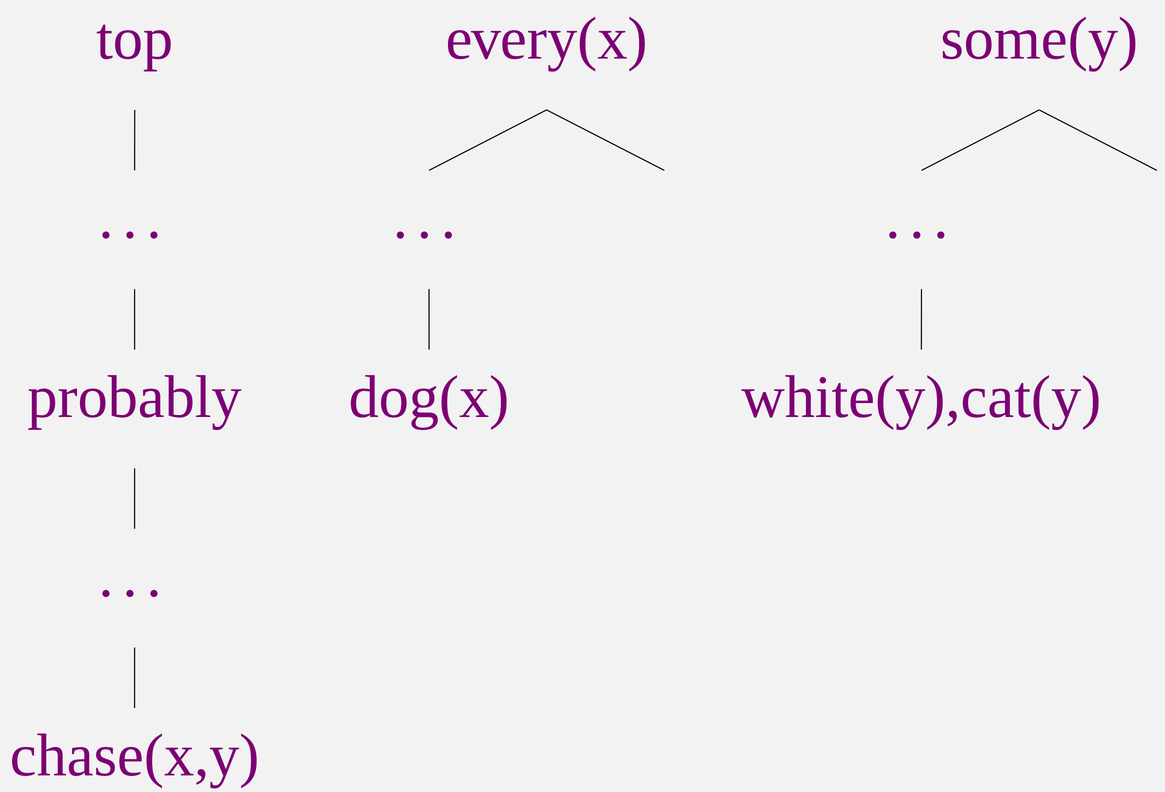
Partially constrained quantifier scope (2/5)

- Every nephew of some famous politican runs.
  - But not:
  - every(x,run(x),some(y,famous(y) $\wedge$ polician(y), nephew(x,y)))
  - 'Everyone who runs is a newphew of a famous politician.'

Partially constrained quantifier scope (3/5)



Partially constrained quantifier scope (4/5)



Partially constrained quantifier scope (5/5)

- $\langle h0, \{h2 : \text{every}(x, h3, h4), h5 : \text{nephew}(x, y), h6 : \text{some}(y, h7, h8), h9 : \text{politician}(y), h9 : \text{famous}(y), h10 : \text{run}(x)\}, \{h1 =_q h10, h7 =_q h9, h3 =_q h5\}\rangle$
- $\langle h0, \{h1 : \text{every}(x, h2, h3), h4 : \text{dog}(x), h5 : \text{probably}(h6), h7 : \text{chase}(x, y), h8 : \text{some}(y, h9, h10), h11 : \text{white}(y), h11 : \text{cat}(y)\}, \{h0 =_q h5, hw =_q h4, h6 =_q h7, h9 =_q h11\}\rangle$

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 compipisition: 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 ARGn 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
- $\longrightarrow$ 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 $\longleftrightarrow$ indices
- ARGn $\longleftrightarrow$ handles
- LBL $\longleftrightarrow$ 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.

$$\boxed{A}\begin{bmatrix} \textit{dlist} & \\ \text{LIST} & \boxed{1}\begin{bmatrix} \textit{ne-list} & \\ \text{FIRST} & \textit{item1} \\ \text{REST} & \boxed{2}\ \textit{list} \end{bmatrix} \\ \text{LAST} & \boxed{2} \end{bmatrix} \quad \boxed{B}\begin{bmatrix} \textit{dlist} & \\ \text{LIST} & \boxed{3}\begin{bmatrix} \textit{ne-list} & \\ \text{FIRST} & \textit{item2} \\ \text{REST} & \boxed{4}\ \textit{list} \end{bmatrix} \\ \text{LAST} & \boxed{4} \end{bmatrix}$$

- 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

$$\boxed{A}\begin{bmatrix} \textit{dlist} & \\ \text{LIST} & \boxed{1}\begin{bmatrix} \textit{ne-list} & \\ \text{FIRST} & \textit{item1} \\ \text{REST} & \begin{bmatrix} \textit{ne-list} & \\ \text{FIRST} & \textit{item2} \\ \text{REST} & \boxed{2}\ \textit{list} \end{bmatrix} \end{bmatrix} \\ \text{LAST} & \boxed{2} \end{bmatrix}$$

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?

Semantic compositionality in action

```
basic-unary-phrase := phrase &
  [ SYNSEM.LOCAL.CONT [ RELS [ LIST #first,
                               LAST #last ]],
    C-CONT [ RELS [ LIST #mid,
                    LAST #last ]],
    ARGS < sign & [ SYNSEM.LOCAL
            [ CONT [ RELS [ LIST #first,
                            LAST #mid ]]]]>].
```

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.ARGn.

ARGn $\leftrightarrow$ *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 $\leftrightarrow$ *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 ] ] ].
```

$LBL \leftrightarrow LBL$

```
isect-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

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