Linking Semantics for Modification

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What this talk is about

- Inferential properties of modification
- Interface between syntax and semantics: glue logic for deriving logical forms from syntactic structures
- Lexical denotations of verbs
- Mode of composition for individual-denoting and quantificational arguments and modifiers

Arity expansion effected by modifiers

- How is arity expansion of a basic predicate relation brought about?
  - e.g. basic binary relation *stab*, as in *Brutus stabbed Caesar*, is expanded to a ternary relation in *Brutus stabbed Caesar with a knife*
- What is the incremental contribution of modifiers such as *with a knife, to most cities, from every candidate*?

Diamond entailment patterns

(1) a. Brutus stabbed Caesar with a knife in the forum $\models$
b. Brutus stabbed Caesar with a knife $\models$
c. Brutus stabbed Caesar

(2) a. Brutus stabbed Caesar with a knife in the forum $\models$
b. Brutus stabbed Caesar in the forum $\models$
c. Brutus stabbed Caesar

(3) a. Brutus stabbed Caesar in the forum $\not\models$
b. Brutus stabbed Caesar with a knife

(4) a. Brutus stabbed Caesar with a knife $\not\models$
b. Brutus stabbed Caesar in the forum

Modification the Montagovian tradition

- Fixed-arity predicates
- Fixed argument order
- Non-uniform treatment of arguments and other modifiers
- Quantification requires traces for quantifying in or proliferation of types
- Meaning postulates to capture inferential properties of modifiers.

The (neo-)Davidsonian solution

- Use events to tie together modifiers with the predication they are modifying
- Modifiers are co-predicates of the event variable
- Logic of modifiers reduced to conjunctive elimination, i.e. intersective treatment of modifiers

(5) $\exists e(\mathit{stab}(e) \wedge \textsc{agent}(e, \mathit{brutus})) \wedge \textsc{pat}(e, \mathit{caesar}))$

(6) $\exists e \exists x(\mathit{stab}(e) \wedge \textsc{agent}(e, \mathit{brutus})) \wedge \textsc{pat}(e, \mathit{caesar}) \wedge \mathit{knife}(x) \wedge \textsc{with}(e, x))$

Some limitations of (neo-)Davidsonian event semantics

- Failures of modifier dropping inferences
- Saturating vs. non-saturating modifiers
- Modifier adding inferences
- Quantification
- Domain narrowing for cascading locative and temporal modifiers
- These limitations stem directly from the primary mode of semantic composition, intersection between sets of events.

Failures of modifier dropping inferences

(7) a. Brutus stabbed Caesar with a knife in the forum $\models$
b. Brutus stabbed Caesar with a knife $\models$
c. Brutus stabbed Caesar

But...

(8) a. Less than 30 senators stabbed Caesar with a knife in the forum $\not\models$
b. Less than 30 senators stabbed Caesar with a knife $\not\models$
c. Less than 30 senators stabbed Caesar

More failures of modifier dropping inferences

(9) a. Last year, Ed avoided getting into trouble for at least three days. $\not\models$

b. Last year, Ed avoided getting into trouble.

(10) a. Yesterday, Beth smoked cigars continuously between 1PM and 2PM. $\not\models$

b. Yesterday, Beth smoked cigars continuously.

But can't we just scope the quantifiers out?

- Pick any sentence with a strong or non-$\uparrow$MON quantifier: it can't be treated it directly in a Davidsonian fashion (= *intersectively*).
- One standard solution is to scope out quantifiers and give existential closure over events narrow scope (Landman 2000)
- This leads to non-uniformity, and is sometimes problematic:

(11) Beth quickly ate every donut.

Or introduce multiple events?

- Another solution is to have events on the outside and on the inside related by a subpart relation (Krifka 1989)
- Need to build special minimality/maximality into the semantics and allow for arbitrary summing of events

(12) Every man jumped.

(13) $\lambda e.\forall x(man(x) \rightarrow \exists e'(e' \sqsubseteq e \wedge jump(e') \wedge \textsc{agent}(e', x))) \wedge e = \bigoplus \lambda e'.\exists y(man(y) \wedge jump(e') \wedge \textsc{agent}(e', y))$

Temporal modifiers

(14) a. In 2010, it rained every day. $\models$
b. In 2010, in July it rained every day.

(15) a. In 2010, in July it rained every day. *not* $\models$
b. In 2010 it rained every day.

More non-intersectivity — cascading modifiers

- Arbitrary numbers of locative and temporal modifiers may be interleaved with each other and other modifiers.
- They do not always combine intersectively: one modifier can restrict the domain of the next.

(16) Last year in Rome on 15th March, Brutus stabbed Caesar in the forum with a knife at midday in front of a large crowd of onlookers.

(17) Last year in Germany, one or two people were mugged every couple of hours in a few hidden corners of campus every weekday in some of the more dangerous university towns.

Part I

Introducing linking semantics

Event types

- In a neo-Davidsonian analysis of e.g. *No woman laughed*, it's tough to identify a set of non-eating events.
- So we don't know what set of events to provide to the temporal modifier in *On Thursday, no woman laughed*.
- But *On Thursday* doesn't need to see a whole event: it only needs an event time.
- If we use event types, partial descriptions of events, then we can associate *No woman laughed* with a set of event types, i.e. all those partial descriptions such that if you add a woman as agent, they are not *laughings*.
- First version of proposal: use sets of event types instead of sets of events.

Implementing event types

- Take roles as basic rather than events; mediate between syntax and semantics using partial assignment functions mapping roles to individuals.
- So verbs and all projections of verbs denote sets of assignments: *Linking Structures*.
- We can understand interpretation (pseudo-)dynamically: verb meaning gives a set of assignments, and subsequent modifiers iteratively modify the set.

Official version of linking semantics

- We use syntactic roles, e.g. SUBJ for subjects, OBJ for direct objects, but also e.g. TIME, WORLD, LOC (for external locations), ILOC (for internal locations).
- This syntactification has advantages for the syn/sem interface (not discussed in detail), e.g. allowing a difference between the interpretation of active *help* and that for passive *be helped*.
- E.g. "help me" denotes the set of assignments mapping SUBJ, TIME, WORLD, LOC onto someone who helps me, some time when they help me etc.
- Note that whereas "help" contains assignments defined for OBJ, "help me" does not.

Verbs

- For any verb V, a set of canonical arguments is given by C(V)
- Thus {T(IME), W(ORLD), LOC(ATION), SUBJ} for an intransitive verb, {T, W, LOC, SUBJ, OBJ} for a transitive verb
- Or e.g. {T, W, LOC, SUBJ, OBJ, ILOC} for *put* (where ILOC means *internal location*).

Meaning postulates for all verbs, models

Argument reduction axiom If an assignment is in the extension of the verb then any assignment differing only by lacking a value for some role $\notin C(\mathrm{V})$ is also in the verb's extension.

Temporal closure axiom What happens in an interval happens in all larger intervals (i.e. there are corresponding assignments mapping T to the larger intervals.)

Locative closure axiom (Similar!) What happens at an external location happens at all larger locations.

Example: stab

- Suppose Brutus b stabbed Caesar c in back(c) in the forum f at midday on 15-3-44BC in world w, and the model involves no other stabbings in that world or any other.
- Then I(stab) contains
  $[\textsc{w}\ w;\ \textsc{t}\ 12PM{:}15\text{-}3\text{-}44BC;\ \textsc{loc}\ f;\ \textsc{subj}\ b;\ \textsc{obj}\ c;\ \textsc{iloc}\ \mathrm{back}(c)]$
- By *argument reduction* it must also contain:
  $[\textsc{w}\ w;\ \textsc{t}\ 12PM{:}15\text{-}3\text{-}44BC;\ \textsc{loc}\ f;\ \textsc{subj}\ b;\ \textsc{obj}\ c;\ \textsc{loc}\ f]$
  $[\textsc{w}\ w;\ \textsc{t}\ 12PM{:}15\text{-}3\text{-}44BC;\ \textsc{loc}\ f;\ \textsc{subj}\ b;\ \textsc{obj}\ c]$

Example: more stabbing

- By *temporal closure*, I(stab) will also contain e.g.
  [W w; T (11AM-1PM):15-3-44BC; SUBJ b; OBJ c]
  [W w; T 15-3-44BC; LOC f; SUBJ b; OBJ c]
  [W w; T 44BC; LOC f; SUBJ b; OBJ c]

Modifiers

- All arguments and modifiers, e.g. tense, negation, modals, subject and object DPs, PPs, adverbs, have the same type.
- The modifier type: a mapping from input linking structures to output linking structures.

DPs

- Modifier type meanings are derived in two stages.
- First we obtain a standard GQ.
- Then we map it to a modifier type, relative to a role label.

Saturating and non-saturating modifiers

- There are two sorts of modifiers: saturating and restricting.
- A saturating role (e.g. SUBJ) maps a set of assignments to a new set no longer defined on that role. (Prevents doubling of subjects.)
- Restricting roles (W, T, LOC) allow arbitrarily many modifiers (modals, temporal modifiers, and locatives).

Assignments

- f, g range over (partial) role assignments, and x over individuals, which include times and worlds.
- $g =_{\mathrm{R}} f$ means that g differs from f at most by R.
- $f + [\mathrm{R}, x]$ adds an assignment to f.
- $f[\mathrm{R}, x]$ modifies an assignment in f.

Definition for saturating modifiers

Definition (Simplified version — individual denoting DPs)

$$I[\![\mathrm{DP{:}\textsc{role}}]\!]O \quad \text{iff} \quad O = \lambda f\ I(f + [\textsc{role}, [\![\mathrm{DP}]\!]^f])$$

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Definition (Official version — GQ denoting DPs)

$$I[\![\mathrm{DP{:}\textsc{role}}]\!]O \quad \text{iff} \quad O = \lambda f\ [\![\mathrm{DP}]\!]^f(\lambda y\ I(f + [\textsc{role}, y]))$$

Prepositions

- For purposes of this talk, it suffices that prepositions help determine a role, and we simplify by ignoring their lexical semantics.
- But more generally, we need to combine the lexical semantics of prepositions with quantificational determiners in such a way that the determiner scopes over the preposition.
- Thus:
  $[\![\text{P DP}]\!] = \lambda R\ [\![DP]\!](\lambda x \exists y [\![P]\!](x)(y))$

The rule of clausal composition

Definition

$[\![X \text{ Mod}]\!]L \quad \text{iff} \quad \exists L' \; [\![X]\!]L' \text{ and } L'[\![\text{Mod}]\!]L$

Truth and entailment

Definition (Truth)

$w, t, l \models S$ iff $[\![S]\!]O$ and $[\textsc{w}\ w; \textsc{t}\ t; \textsc{loc}\ l] \in O$

Definition (Entailment)

$S \models S'$ iff $\forall w, t, l \;\; w, t, l \models S \;\Rightarrow\; w, t, l \models S'$

Restriction

- Applying "at midday":T to I(stab) returns assignments where $\text{T} \mapsto$ an interval containing a unique midday.
- Intuition: "at midday" has a defined meaning only in these larger intervals.
- Similarly "the forum":LOC yields assignments mapping LOC onto a location in which "the forum" is uniquely defined, e.g. Rome.

Definition for non-saturating modifiers

Definition

$$I[\![\text{DP:}\textsc{role}]\!]O \text{ iff } \quad O = \lambda f\ [\![\text{DP}]\!]^{f}(\lambda y\ I(f[\textsc{role}, y]))$$

Definition for saturating modifiers

Definition

$$I[\![\mathrm{DP}{:}\textsc{role}]\!]O \text{ iff } \qquad O = \lambda f\ [\![\mathrm{DP}]\!]^{f}(\lambda y\ I(f + [\textsc{role}, y]))$$

Definition for non-saturating modifiers

Definition

$$I[\![\mathrm{DP{:}\textsc{role}}]\!]O \text{ iff } \qquad O = \lambda f\ [\![\mathrm{DP}]\!]^{f}(\lambda y\ I(f[\textsc{role}, y]))$$

Side remark: further dependencies are possible

$[\![\textit{himself}]\!]^f = \lambda P[P(f(\textsc{role}))]$, where ROLE is e.g. SUBJ.

Further modifiers

$$
\begin{aligned}
I[\![\text{past} : \textsc{t}]\!]O \quad &\text{iff} \quad O = \lambda f\ [I(f[\textsc{t}, max(i, f(\textsc{t}) \sqsupseteq i < now)])] \\
I[\![\text{might} : \textsc{w}]\!]O \quad &\text{iff} \quad O = \lambda f\ \exists w\ I(f[\textsc{w}\ w]) \\
I[\![+passive]\!]O \quad &\text{iff} \quad O = \lambda f\ \exists g\ I(g) \wedge \\
&\qquad f + [\textsc{obj}, g(\textsc{obj})] = g[\textsc{subj}, g(\textsc{obj})] \quad \vee \\
&\qquad f + [\textsc{obj}, g(\textsc{obj})] = g[\textsc{subj}, g(\textsc{obj})] + [\textsc{by}, g(\textsc{subj})]
\end{aligned}
$$

Negation needs an additional constraint on domains so that e.g. “Mary didn’t rain Fred with a hammer” is undefined rather than false:

$$
I[\![\text{not}]\!]O \quad \text{iff} \quad O = \lambda f\ \neg I(f) \wedge \exists g\ I(g) \wedge dom(f) = dom(g)
$$

Example derivation

$$
\begin{array}{lll}
[\![\text{Mary}]\!]^f & = & \lambda P[P(m)] \\
I[\![\text{Mary:}\textsc{subj}]\!]O & \text{iff} & O = \lambda f[\lambda P[P(m)](\lambda x\ I(f + [\textsc{subj}, x]))] \\
 & \text{iff} & O = \lambda f[I(f + [\textsc{subj}, m])] \\
I[\![\textit{past}\text{:}\textsc{t}]\!]O & \text{iff} & O = \lambda f[I(f[\textsc{t}, \mathit{max}(i, \mathit{now} > i \sqsubseteq f(\textsc{t}))])] \\
[\![\text{laughed}]\!]O & \text{iff} & [\![\text{laugh}]\!][\![\text{past:}\textsc{t}]\!]O \\
 & \text{iff} & O = \lambda f[\text{laugh}'(f[\textsc{t}, \mathit{max}(i, \mathit{now} > i \sqsubseteq f(\textsc{t}))])] \\
[\![\text{Mary laughed}]\!]O & \text{iff} & [\![\text{laughed}]\!][\![\text{Mary:}\textsc{subj}]\!]O \\
 & \text{iff} & O = \lambda f[\text{laugh}'(\\
 & & \quad f[\textsc{t}, \mathit{max}(i, \mathit{now} > i \sqsubseteq f(\textsc{t}))] + [\textsc{subj}, m])] \\
\multicolumn{3}{l}{M, w, t, l \models \text{Mary laughed}} \\
 & \text{iff} & \exists O\ [\![\text{Mary laughed}]\!]O \ \wedge\ O([\textsc{w}\ w; \textsc{t}\ t; \textsc{l}\ l]) \\
 & \text{iff} & \text{laugh}'([\textsc{w}\ w; \textsc{t}\ \mathit{max}(i, \mathit{now} > i \sqsubseteq t); \textsc{l}\ l; \textsc{subj}\ m])
\end{array}
$$

Part II

Advantages and applications

Minimization of type-driven polysemy

- Due to type uniformity of LS, many expressions which in MG would be polysemous across multiple type instantiations can instead be given a single meaning.
- Thus e.g. the LS analysis of modals and negation is not specific as to whether they are VP or S modifiers.

Davidsonian inference

The following is valid in LS:

(18) Brutus stabbed Caesar with a knife in the forum $\models$

(19) Brutus stabbed Caesar with a knife $\models$

(20) Brutus stabbed Caesar

Reverse Davidsonian inference

The following is also valid in LS:

(21) Less than 30 senators stabbed Caesar $\models$

(22) Less than 30 senators stabbed Caesar with a knife $\models$

(23) Less than 30 senators stabbed Caesar with a knife in the forum

Generalized Davidsonian properties

- If everything is upward monotone, we get standard Davidsonian inferences.
- A downward monotone environment produces reverse Davidsonian inferences.
- Following example correctly analyzed:

(24) a. Last year, Ed avoided getting into trouble. $\models$

b. Last year, Ed avoided getting into trouble for at least three days.

More failures of modifier dropping inferences

- Generally Davidsonian inferences arise from the Argument Reduction Axiom.
- But even with upward monotonicity, this axiom only guarantees Davidsonian inferences for modifiers which are *distributive* over the individual assignments in a Linking Structure.
- Because LS modifiers are not intersective, they need not be distributive.
- E.g. *continuously* is not distributive, but quantifies over assignments, explaining why:

(25) a. Yesterday, Beth smoked cigars continuously between 1PM and 2PM. $\not\models$

b. Yesterday, Beth smoked cigars continuously.

Scope

- Different scopings correspond to different orders of application
- No need for traces
- These are shared features with neo-Davidsonian approaches like Krifka's

(26) Every cat chased a mouse

(27) surface scope: $\forall > \exists$
(every cat$_{\mathrm{SUBJ}}$(some mouse$_{\mathrm{OBJ}}$(chase)))

(28) inverse scope: $\exists > \forall$
(some mouse$_{\mathrm{OBJ}}$(every cat$_{\mathrm{SUBJ}}$(chase)))

Cascading modifiers

(29) Last year in Rome on 15th March, Brutus stabbed Caesar in the forum with a knife at midday in front of a large crowd of onlookers.

(30) Last year on 15th March, Brutus stabbed Caesar at midday.

- Such cascading combinations of modifiers are handled by LS with no additional definitions (except for the lexical semantics of specific prepositions), and with improvements over prior proposals.

Quantified non-saturating modifiers

(31) Most years, it rained every day.

(32) In most countries, it rained in every city.

- As Dowty (1979) noted, standard event-based treatments of non-saturating modifiers cannot handle quantified modifiers.
- Even quantifying-in, by itself, does not derive the correct readings in such approaches.
- LS correctly models the fact that wider scope non-saturating modifiers define the domain for narrower scope operators.

Other recent work on temporal modifiers

- There have been some recent breakthroughs in work on temporal modifiers: Pratt and Francez (2001), von Stechow (2002), and Francez and Steedman (2006).
- All require significant complication of Montagovian types, and a non-uniform treatment of temporal modifiers.
- LS has similar coverage of cascades of temporal modifiers, but is more uniform, and has empirical advantages.

Other recent work on temporal modifiers (cont.)

- Unlike any previous system, LS predicts the following contrast simply as a result of a general precedence principle: extraposed elements are processed later.

(33) ? Every day, it rained last year.

(34) Every day it rained, last year.

(35) Last year, it rained every day.

Conclusion

- Like MG: Compositionality, quantification etc.
- Unlike MG:
  1. more uniform typing
  2. no traces
  3. natural treatment of free word order
  4. alternations (not discussed here)
  5. optionality

Conclusion (cont.)

- Like neo-Davidsonian approaches: basic modifier dropping inferences, optionality
- Unlike such approaches:
  1. failures of modifier dropping inferences
  2. quantification and scope
  3. dependencies between modifiers
  4. saturation and restriction

Three final insights

1. Using event types (or a syntactic equivalent) instead of events allows a treatment of quantification.
2. Montague saturates, and Davidson restricts, but we need both.
3. Restriction is asymmetric (not just intersection). . . one modifier can define the domain for another.