On the Logic of Verbal Modification

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Basic idea

- We will consider a halfway house between Montague Grammar and Davidsonian Event Semantics.
- We take roles as basic rather than events, and mediate between syntax and semantics using partial assignment functions mapping roles to individuals.
- Thus verbs and all projections of verbs denote sets of assignments, or what we call *Linking Structures*.
We use syntactic roles where motivated, e.g. ARG1 for subjects, ARG2 for direct objects, but also e.g. TIME, WORLD, ELOC (for external locations), ILOC (for internal locations).

E.g. “help me” denotes the set of assignments which map ARG1, TIME, WORLD onto someone who helps me, some time when they help me, and some possible world in which the relation holds, respectively.

Note that whereas “help” is defined for ARG2, “help me” is not, since ARG2 has been saturated.
Formalization

- We map a fragment of English syntactic trees into a type-theory inspired meta-language.
- Direct mapping into type theory, e.g. with role names as privileged constants of a distinct role type, is straightforward, but use of partiality complicates the embedding. (cf. Muskens)
Assignments

- $f, g$ range over (partial) role assignments, and $x$ over individuals, which include times and worlds.
- $g =_R f$ means that $g$ differs from $f$ at most by $R$.
- $f + [R, x]$ is defined when $f$ does not have $R$ in its domain, then maps $R$ to $x$.
- $f[R, x]$ is defined when $f$ does have $R$ in its domain, then maps $R$ to $x$. 
Models

- A model $\mathcal{M}$ is a structure $\langle I, D_w, D_e \rangle$.
- A verb is mapped by $I$ to (t.c.f.o.) a set of assignments, a noun to a set of individuals.
- We take time intervals and locations to be privileged individuals in $D_e$ obeying standard axioms, such that $\sqsubseteq$ denotes inclusion, and $\leq$ denotes temporal precedence (no overlap).
For any verb V, a set of canonical arguments is given by $C(V)$

Thus \{T(IME), W(ORLD), ARG1\} for an intransitive verb, \{T, W, ARG1, ARG2\} for a transitive verb

Or e.g. \{T, W, ARG1, ARG2, 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 $\notin C(V)$ is also in the verb’s extension.

**Temporal closure axiom** What holds at an interval holds at all larger intervals (i.e. there are corresponding assignments mapping $T$ to the larger intervals.)

**Locative closure axiom** What holds at an external location holds at all larger locations (i.e. there are corresponding assignments mapping $ELOC$ to larger spaces.)
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
  
  $\left[ w \cdot t 12PM:15-3-44BC; \text{ARG1} \ b; \text{ARG2} \ c; \text{ILOC} \ \text{back}(c); \text{ELOC} \ f \right]$

- By *argument reduction* it must also contain:
  
  $\left[ w \cdot t 12PM:15-3-44BC; \text{ARG1} \ b; \text{ARG2} \ c; \text{ILOC} \ \text{back}(c) \right]$
  
  $\left[ w \cdot t 12PM:15-3-44BC; \text{ARG1} \ b; \text{ARG2} \ c; \text{ELOC} \ f \right]$
  
  $\left[ w \cdot t 12PM:15-3-44BC; \text{ARG1} \ b; \text{ARG2} \ c \right]$
Example: more stabbing

- By *temporal closure*, I(stab) will also contain e.g.
  
  \[
  [w \ b; t \ (11AM-1PM):15-3-44BC; \text{ARG1 } b; \text{ARG2 } c]
  
  [w \ b; t \ 15-3-44BC; \text{ARG1 } b; \text{ARG2 } c]
  
  [w \ b; t \ 44BC; \text{ARG1 } b; \text{ARG2 } c]
  
- By *locative closure*, it will also contain e.g.
  
  \[
  [w \ b; t \ 44BC; \text{ARG1 } b; \text{ARG2 } c; \text{ELOC Rome}]
  \]
All arguments and modifiers, e.g. tense, negation, modals, subject and object DPs, PPs, adverbs, have the same type.

They map linking structures to linking structures.
Nominal predicates and determiners have standard extensional meanings, except are interpreted wrt to assignments, which gives them access to a world, time, and location.

Note: better to analyze nouns like verbs, but not today!

Syntactic role labels act on DP meanings to produce verbal modifier meanings.
Saturating and non-saturating modifiers

- There are two sorts of modifiers: saturating and non-saturating.
- A saturating role, such as $\text{ARG1}$, forms a modifier which maps a set of assignment functions to a new set that is no longer defined on that role: this prevents a verb from combining with two subjects.
- The non-saturating roles $\text{W}$, $\text{T}$, and $\text{ELOC}$ allow arbitrarily many modifiers (modals, temporal modifiers, and locatives).
Example: saturating a “stabbing” role

Applying Caesar: \texttt{ARG2} to \texttt{l(stab)}, and assuming
\[ \texttt{Caesar}\] = \lambda \, P\, P(c),
will leave assignments like:

\[
\begin{array}{l}
[w \ w; \ t \ 12PM:15-3-44BC; \ ARG1 \ b; \ ILOC \ back(c); \ ELOC \ f] \\
[w \ w; \ t \ 12PM:15-3-44BC; \ ARG1 \ b; \ ILOC \ back(c)] \\
[w \ w; \ t \ 12PM:15-3-44BC; \ ARG1 \ b; \ ELOC \ f] \\
[w \ w; \ t \ 12PM:15-3-44BC; \ ARG1 \ b] \\
[w \ w; \ t \ (11AM-1PM):15-3-44BC; \ ARG1 \ b] \\
[w \ w; \ t \ 15-3-44BC; \ ARG1 \ b] \\
[w \ w; \ t \ 44BC; \ ARG1 \ b] \\
[w \ w; \ t \ 44BC; \ ARG1 \ b; \ ELOC \ Rome]
\end{array}
\]
Example: saturating a “stabbing” role (cont.)

- Applying Brutus: \texttt{ARG1}, or both Brutus: \texttt{ARG1} and Caesar: \texttt{ARG2} would have a similar effect, producing LSs containing assignments which give no value to \texttt{ARG1}, or to both \texttt{ARG1} and \texttt{ARG2}.

- Similarly for \texttt{ILOC}, though here assignments that aren’t defined on \texttt{ILOC} are thrown out too.

- Applying Brutus: \texttt{ARG2} would just produce the empty set in this case, since nobody stabbed Brutus.
Definition for saturating modifiers

Consider some verbal projection with denotation \( L \), modified by some \( X \), e.g. a DP, with a saturating role \( \text{srole} \).

Assume \( X \) denotes a generalized quantifier.

Applying the modifier produces a new linking structure containing assignments \( f \) for which \( X \) holds of \( \lambda y \ L(f + [\text{srole}, y]) \).

\[
[X:\text{sROLE}]_M = \lambda \lambda f [[X]]_M^f(\lambda y \ L(f + [\text{sROLE}, y]))
\]
Example: a non-saturating modifier “stabbing” role

- Applying “at midday”:\( T \) to \( l(\text{stab}) \) returns all the assignments where \( T \) is mapped onto an interval containing a unique midday.

- Intuition: it is only in these larger intervals that “at midday” has a defined meaning. (Note: the uniqueness requirement could be pragmatic rather than semantic.)

- Similarly “the forum”:\( \text{ELOC} \) applies to \( l(\text{stab}) \) to yield assignments that map \( \text{ELOC} \) onto a location in which “the forum” is uniquely defined, e.g. Rome.
Definition for non-saturating modifiers

\[
[X: \text{NROLE}]_M = \lambda L \lambda f[[X]_M^f(\lambda y L(f[\text{NROLE}, y]))]
\]
Definition for saturating modifiers

\[
[X: \text{srole}]_M = \lambda L \lambda f \, [[X]]_M^f (\lambda y L (f + [\text{srole}, y]))
\]
Definition for non-saturating modifiers

\[ [X:\text{NROLE}]_M = \lambda L \lambda f [[X]_M^f (\lambda y L f [\text{NROLE}, y])] \]
Definition for saturating modifiers

\[
[X:\text{NROLE}]_M = \lambda L \lambda f \left[ \lambda y L \left( f [\text{NROLE}, y] \right) \right]
\]

Note: \( X \) is interpreted wrt \( f \), and so can be interpreted relative to the world, time, and location given by \( f \).
A disambiguated language

- We interpret structures in which syntax has labeled non-logical modifiers with role names.
- But we assume by default that any unlabeled non-expletive preverbal DP is labeled $\text{ARG}_1$, and any unlabeled immediately postverbal DP is labeled $\text{ARG}_2$.
- Hence:
  
  \[
  \text{Every day:} T \left[ \left[ \text{most people} \right] \left[ \text{eat} \left[ \text{two carrots} \right] \right] \right] \equiv \\
  \text{Every day:} T \left[ \left[ \text{most people}: \text{ARG}_1 \right] \left[ \text{eat} \left[ \text{two carrots}: \text{ARG}_2 \right] \right] \right]
  \]
A disambiguated language (cont.)

- We artificially order all modifiers, notating scope with numeric superscripts.
- Surface order provides a default. Hence e.g.:
  \[\text{Every day}^T \text{ [most people} \text{ eat [two carrots}]] \equiv \text{Every day}^1 \text{ [most people}^2:\text{ARG1 eat [two carrots}^3:\text{ARG2]}\]}
- Scope Constraint: the interpretation rules will guarantee that all fronted and postposed modifiers behave as if they have lower numbers (i.e. wider scope) than all non-fronted modifiers.
- Future work: allow syntax, semantics and pragmatics to mutually constrain role labeling and scope ordering.
Interpreting the language

\[ [S]_M = [\text{Mod}^1]_M([\text{Mod}^2]_M(\ldots [S']_M)\ldots) \]

where \( S \) is a tree consisting of appropriately numbered modifiers fronted before or postposed after a sentence \( S' \)

\[ [S]_M = [\text{Mod}^i]_M([\text{Mod}^{i+1}]_M(\ldots ([\text{tense}]_M(I(V)))\ldots) \]

where \( S \) is a tree consisting of appropriately numbered non-fronted modifiers and a tensed verb \( V \)

- Note: could equally well have interpreted trees compositionally, raising modifiers to get wide scope.
- Either way no traces are needed.
Interpreting the language

\[ [S]_M = [\text{Mod}^1]_M([\text{Mod}^2]_M(\ldots [S']_M\ldots)) \]

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where \( S \) is a tree consisting of appropriately numbered non-fronted modifiers and a tensed verb \( V \)

- Note: could equally well have interpreted trees compositionally, raising modifiers to get wide scope.
- Either way no traces are needed.
For most examples considered here and in the paper, 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:

\[
\llbracket [P \; DP] \rrbracket_M = \lambda R \llbracket DP \rrbracket_M (\lambda x \exists y [P]_M(x)(y))
\]
Examples of logical operators

\[
\text{[past]}_M = \lambda L \lambda f \ f(T) < \text{now}_M \\
\text{[and]}_M = \lambda L_1 \lambda L_2 \lambda f \ L_1(f) \land L_2(f) \\
\text{[might]}_M = \lambda L \lambda f \ \exists w \ L(f[w\ w]) \\
\text{[\*passive]}_M = \lambda L \lambda f \ \exists g \ L(g) \land \\
\quad f + [\text{ARG2}, g(\text{ARG2})] = g[\text{ARG1}, g(\text{ARG2})]
\]

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

\[
\text{[be/does not]}_M = \lambda L \lambda f \ \neg L(f) \land \exists g \ L(g) \land \text{dom}(f) = \text{dom}(g)
\]
Truth and entailment

Definition

Support \( M, w, t, l \models S \iff \llbracket S \rrbracket_M([w \ w; \ t \ t; \ e\text{loc} \ l]) \) (we ignore e\text{loc} where not relevant)

Truth \( S \) is true wrt \( M, w \) in a context if a time \( t \) and location \( l \) is salient such that \( M, w, t, l \models S \).

Accommodation (loosely): if \( t \) and \( l \) are maximal intervals / locations such that \( \llbracket S \rrbracket_M([w \ w; \ t \ t; \ e\text{loc} \ l]) \) is defined (i.e. true or false) wrt \( M \) and \( w \), then \( t \) and \( l \) are salient in contexts of interpretation for \( S \).

Entailment \( S \) models \( S' \) iff \( \forall M, w, t, l \ M, w, t, l \models S \Rightarrow M, w, t, l \models S' \)
Example derivation

\[ [\text{Mary}]_M^f \]
\[ [\text{Mary:ARG1}]_M \]

\[ = \lambda P[P(m)] \]
\[ = \lambda L \lambda f[\lambda P[P(m)](\lambda x L(f + [\text{ARG1}, x])))] \]
\[ = \lambda L \lambda f[L(f + [\text{ARG1}, m])] \]

\[ [\text{past}]_M \]
\[ [\text{laughed}]_M \]

\[ = \lambda L \lambda f[L(f) \land f(T) < \text{NOW}] \]
\[ = [\text{past}]_M([\text{laugh}]_M) \]
\[ = \lambda L \lambda g[L(g) \land g(T) < \text{NOW}](\text{laugh}') \]
\[ = \lambda g[\text{laugh}'(g) \land g(T) < \text{NOW}] \]

\[ [\text{Mary laughed}]_M \]

\[ = [\text{Mary:ARG1}]_M([\text{laughed}]_M) \]
\[ = \lambda f[\text{laugh}'(f + [\text{ARG1}, m]) \land f(T) < \text{NOW}] \]

\( M, w, t \models \text{Mary laughed} \) iff \( \text{laugh}'([w, w; T, t; \text{ARG1}, m]) \land t < \text{NOW} \)

\( \text{Mary laughed is true}_{M, w} \) iff \( \exists t \text{ laugh}'([w, w; T, t; \text{ARG1}, m]) \)

(by accommodation of maximal defined interval, temporal closure)
Part II

The view

6 Davidsonian inference
7 Scope
8 Alternations
9 Cascading modifiers
10 Summary
11 Shameless plug
The following is valid in LS:

(1) Brutus stabbed Caesar with a knife in the forum \models
(2) Brutus stabbed Caesar with a knife \models
(3) Brutus stabbed Caesar
Reverse Davidsonian inference

The following is also valid in LS:

(4) Less than 30 senators stabbed Caesar \( \models \)

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

(6) Less than 30 senators stabbed Caesar with a knife in the forum
Generalized Davidsonian properties

- If all modifiers in a sentence $S$ are upward monotone, and $S'$ differs from $S$ by addition of an upward monotone modifier operating on an optional role, then $S' \models S$ in Linking Semantics.

- If all modifiers bar one in a sentence $S$ are upward monotone, and the other is downward monotone, and $S'$ differs from $S$ by addition of an upward monotone modifier operating on an optional role, then $S \models S'$ in Linking Semantics.
For a sentence with $n$ fronted modifiers, and $m$ non-fronted modifiers, LS will in general produce $n!m!$ scopings, though these may collapse depending on the modifiers.

For example, in LS, given appropriate numberings of the modifiers, "One December day in every Dutch city most children don’t see a bearded man." is predicted to yield 24 truth conditionally distinct readings.
Basic Davidsonian event semantics incorporates no treatment of scope. It is standardly added by quantifying in, leaving separate levels with and without events.

Krifka (1989) is the only fully worked out exception, defining scope-taking quantificational DPs that encode complex events.

However, Krifka’s quantifiers (i) require a non-standard event ontology, (ii) are formally unwieldy, and (iii) require *ad hoc* stipulations to differentiate upward and downward monotone quantifiers.
Due to type uniformity of LS, many expressions which an 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.

Note that it is possible to force LS operators to be sentential modifiers.

E.g. ‘if’ can be given a constraint that its argument is saturated for everything but worlds, locations and times, and can then close these off. This would result in the well-known scope island behavior of ‘if’-clauses.
Linking structures for a verb can encode not only optionality of arguments, but also alternations between argument structures.

Thus we can choose between making e.g. “give” ambiguous, and making it underspecified as regards the dative alternation.

The following MP makes “give” underspecified:

\[ \forall M, f \in I(\text{give}) \]

1. \( \text{ARG3} \in \text{dom}(f) \Rightarrow \exists g \in I(\text{give}) \ g + [\text{ARG3}, g(\text{ARG2})] = f + [\text{ILOC}, f(\text{ARG3})] \)

2. \( \text{ILOC} \in \text{dom}(f) \Rightarrow \exists g \in I(\text{give}) \ f + [\text{ARG3}, f(\text{ARG2})] = g + [\text{ILOC}, g(\text{ARG3})] \)

3. Now “give me chocolates” and “give chocolates to me” involve the same “give.”
(7) Brutus gave me a huge box of Belgian chocolates, and then, shortly after, cheap American candy to all the other senators. **Dative alternation**

(8) Brutus chopped the onions quite effectively, and then the garlic into the tiniest pieces you can imagine. **Transitive/resultative alternation**

(9) Brutus bored Caesar’s friends, and some of them to tears. **Transitive/resultative alternation**

(10) Brutus walked the five miles into town, and then along the lakeside path for a few hours. **Preposition drop alternation**

(11) Popeye climbed the mast, and then along lower topsail yard. **Preposition drop alternation**
In many cases alternations involve different entailments. Thus e.g. for a spray/load alternation we can easily specify LS meaning postulates such that e.g. that (12) entails that the entire collection was downloaded, but that (13) does not. Yet coordination of the alternation variants is still possible (14).

(12) Brutus loaded the 200Gb collection of mp3 files onto Caesar’s ipod.

(13) Brutus loaded Caesar’s ipod with the 200Gb collection of mp3 files.

(14) Brutus loaded his favorite song onto Caesar’s nano, and then Caesar’s ipod with the 200Gb collection of mp3 files.
Why is it that most lexical semantics is not combined with a precise compositional semantics?

Why doesn’t everyone do lexically sensitive Montague Grammar like Dowty, or compositionally precise event semantics like Krifka?
Cascading modifiers

- Natural languages tend to permit arbitrary numbers of locative and temporal modifiers, which may be interleaved with each other and with other modifiers.

(15) 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.

- 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.
Dowty/Baurle examples

(16) Patrick is in Amsterdam today.
(17) Patrick was in Amsterdam today.
(18) Patrick will be in Amsterdam today.

Unlike e.g. von Stechow (2006), we correctly predict that (16) means Patrick is now in Amsterdam, (17) that he was here in a part of today before now, and (18) that he will be in Amsterdam in a part of today after now.

Intuition: the fact that we can give tense narrow scope (though are not forced to) is what enables this.
Quantified non-saturating modifiers

(19) Most years, it rained every day.
(20) In most countries, it rained in every city.

- Standard event-based treatments of non-saturating modifiers (e.g. Dowty 1979) cannot handle quantified modifiers, because they rely on conjunctive composition.
- Even with quantifying-in, it is impossible to derive the correct readings in such approaches.
- LS gives the correct truth-conditions in such cases, correctly modeling 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 of these require significant complication of Montagovian types, and a treatment of temporal modifiers that is completely different from other modifiers.

- LS has similar coverage of cascades of temporal modifiers, but is more uniform, and has various empirical advantages over each of these proposals.
Unlike any previous system, LS correctly predicts the following contrast:

(21)  ? Every day, it rained last year.
(22)  Every day it rained, last year.
(23)  Last year, it rained every day.
Summary

- Uniform type for all verbal projections.
- Uniform type for all modifiers.
- The inferences motivating Davidsonian event semantics are easily captured, and extended.
- Logical operators do not require polymorphism to work both as VP and S modifiers.
- Unlike Event Semantics, LS provides a uniform treatment of scope.
- Unlike MG, LS recognizes that fixed arity and word-order determined theta-assignment are the exception, not the rule.
Summary (cont.)

- Gives new options for dealing with verbal alternations, directly explaining mismatched modifier cluster coordination facts.
- Provides a more perspicuous mechanism for linking lexical semantics to surface realization than in MG or event semantics.
- A large range of properties of non-saturating modifiers (only partly discussed here) are handled very naturally.
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