# Recursive Adjectival Modification in CLLRS

**Frank Richter**[1]

## 1 Introduction

This paper has two main goals: (1) it presents a Montagovian semantics of recursive adjectival modification in English in LRS (Lexical Resource Semantics, Richter & Sailer (2004)) hand in hand with its implementation in CLLRS (Constraint Language of Lexical Resource Semantics, Penn & Richter (2005)), and (2) it points out that the seemingly straightforward constraint-based rendering of the semantic composition system crucially goes beyond what traditional hole semantic analyses with dominance constraints can do. The important innovation is the underspecification of the semantic functor, i.e. the predicate of a logical expression is underspecified, whereas the holes of dominance constraints into which the labels of other formulæ can be plugged are in the argument positions of functors. While LRS was always able to cover such cases, the syntax and semantics of CLLRS had to be generalized to capture them. A precursor of the present type-logical theory of recursive modification was proposed in a more traditional HPSG feature geometry by Kasper (1997).

## 2 Data and intended semantics

Adjectival modification has not received much attention so far in LRS or in CLLRS, with the exception of the challenging lexical item *different* in Lahm (2018) and Richter (2016). The present focus is on more ordinary adjectives and their adverbial modifiers. In Montague grammars with semantic representations in Intensional Logic and a composition system based on intensional functional application such as the fragment of English in (Gamut, 1991, p. 198), adjectives are semantically treated as functions from properties to sets of entities. In the spirit of lifting types to the most complex case necessary, this permits an account of the fact that a *former senator* is not a senator, and an *alleged senator* may not be a senator. As usual in LRS, our representations are stated in Two-sorted Type Theory, Ty2 (Gallin, 1975). We follow the decision in the English fragment for an automatic reasoning architecture by Hahn & Richter (2015) and add a world index to the representation of adjectives. The type of non-logical constants for adjectives then is $\langle s\langle\langle s\langle et\rangle\rangle\langle et\rangle\rangle\rangle$, with $\langle s\langle et\rangle\rangle$ being the type of nominal constants. Adverbial modifiers of adjectives such as *potentially* in *potentially controversial plan* map an adjective meaning into an adjective meaning, which makes them of type $\langle\langle s\langle\langle s\langle et\rangle\rangle\langle et\rangle\rangle\rangle\langle s\langle\langle s\langle et\rangle\rangle\langle et\rangle\rangle\rangle\rangle$. As we are not concerned with quantification in nominal phrases, we will assume syncategorematic quantifiers as translations of quantificational determiners as in the older LRS literature rather than categorematic (possibly polyadic) quantifiers for simplicity.

[1]Goethe Universität Frankfurt, Germany. Email: f.richter@em.uni-frankfurt.de

In the following examples, we show a few representative noun phrases with adjectival modification and their translation (omitting the translation of the determiner, which would be translated as an existential quantifier binding the variable $x$ in each example). World variables are notated as $w_n$ and are of type $s$; $x, y, z$ are variables of type $e$.

(1) a. (i) (a) controversial plan
(ii) $controversial(w, (\lambda w_2 \lambda y.(plan(w_2, y))), x)$
b. (i) (a) potentially controversial plan
(ii) $(potential(controversial))\,(w, (\lambda w_2 \lambda y.(plan(w_2, y))), x)$
c. (i) (an) invisible pink unicorn
(ii) $invisible(w, (\lambda w_2 \lambda y.(pink(w_2, (\lambda w_3 \lambda z.(unicorn(w_3, z))), y))), x)$
d. (i) (a) clearly potentially genuine unicorn
(ii) $(clearly(potential(genuine)))\,(w, (\lambda w_2 \lambda y.(unicorn(w_2, y))), x)$

The meaning of an adjective has three arguments of type $s$, $\langle s\langle et\rangle\rangle$, and $e$, respectively. Semantically, the two lambda abstractions in (1a) are unnecessary, but they will be technically useful for defining the semantic composition principles in (CL)LRS representations, which is why they are depicted here as well. The same holds for all corresponding lambda abstractions in (1b)–(1d).
Classes of adjectives are traditionally distinguished by the inference patterns they license (Partee, 1995; Kamp & Partee, 1995). We assume that they are given by appropriate meaning postulates (shown here according to (Hahn & Richter, 2015, p. 558)):

(2) a. For every intersective adjective meaning $\alpha$ (*blond, female, Chinese*):
$\exists P^1_{\langle s\langle et\rangle\rangle} \forall w_s \forall P^2_{\langle s\langle et\rangle\rangle} \forall x_e (\alpha(w, P^2, x) \leftrightarrow (P^1(w, x) \wedge P^2(w, x)))$
b. For every subsective, non-intersective adjective meaning $\alpha$ (*tall, genuine, pink*): $\forall P_{\langle s\langle et\rangle\rangle} \forall x_e \forall w_s (\alpha(w, P, x) \rightarrow P(w, x))$
c. For every privative adjective $\alpha$ meaning (*fake, former*):
$\forall P_{\langle s\langle et\rangle\rangle} \forall x_e \forall w_s (\alpha(w, P, x) \rightarrow \neg P(w, x))$

In an HPSG grammar, these could either be stated as part of the representations of words in an appropriate store for meaning postulates (licensed by principles generalizing over the appropriate word classes so that individual lexical entries do not have to mention them separately) or triggered at utterance level by the presence of the respective lexical items in the utterance.
Corresponding meaning postulates are necessary for the adverbial modifiers.

# 3 (CL)LRS Analysis

For reasons of space, this abstract does not separate LRS and CLLRS descriptions but renders the underlying LRS specification in a syntax that loosely follows the CLLRS code of the corresponding grammar implementation. The external content is indicated by ^, the internal content is shown between curly braces ({,}), the main content is underlined, and square brackets ([,]) indicate the subterm relation. Capital letters are metavariables.

(3) pink $\rightsquigarrow$ `^(([{`$\underline{pink}$`}])(W,` $\lambda w_2 \lambda$`X.[` $\boxed{1}$ `(`$w_2$`, X)], X))`
(where $\boxed{1}$ is shared with the MOD|LOC|CONTENT|MAIN value of *pink*)

(4) potentially $\rightsquigarrow$ `[^(([{`$\underline{potential}$`}])([` $\boxed{2}$ `]))]`
(where $\boxed{2}$ is shared with the MOD|LOC|CONTENT|MAIN value of *potentially*)

We need a new clause of the LRS SEMANTICS PRINCIPLE which formulates the semantic combinatoric restrictions for combinations of adjectives (HEAD value *adjective*) with nominal projections and of adverbial modifiers (HEAD value *adj_adv*) with adjectival projections.

(5) SEMANTICS PRINCIPLE, new clause for (adverbial) adjectival modification:
In a *head-adjunct* phrase with an adjective or and adverbial modifier of adjectives as non-head daughter ([HEAD *adj_adv* ∨ *adjective*]), the internal content of the head daughter is a subterm of an argument of the internal content of the non-head daughter.

Moreover, an assumption of the LRS PROJECTION PRINCIPLE must be modified, according to which the internal content is always inherited from the head daughter of a phrase: In accordance with the insight that in adjectival modification (and related structures) syntactic head and semantic head are not the same, in these phrases the internal content is inherited by the phrase from the external content of the non-head daughter.
Given the lexical specifications in (3) and (4), the new clause of the SEMANTICS PRINCIPLE and the modified LRS PROJECTION PRINCIPLE for internal content inheritance, we can now investigate how the semantic representations in (1a)–(1d) are licensed.

(6) unicorn $\rightsquigarrow$ `^[{`$\underline{unicorn}$`(W, X)}]`

Given the (simplified) lexical semantic specification of a noun like *unicorn* in (6), we obtain (7) for *pink unicorn*:

(7) pink unicorn $\rightsquigarrow$ `^[({`$pink$ `(W,` $\lambda w_2 \lambda$`X.[`$\underline{unicorn}$`(`$w_2$`, X)], X)})]`

The internal content of *pink unicorn* (7) is inherited from the external content of *pink* (3) (PROJECTION PRINCIPLE), the variables `X` in (3), (6) and (7) are all identical (a consequence of the lexical specification of *pink*), the predicate *unicorn* in (7) is in the scope of the two lambda abstractions due to the lexical requirement of *pink* and in accordance with the modifier clause of the SEMANTICS PRINCIPLE (5): Since the first argument of *pink* is a world variable of type *s* and the last argument is a variable of type *e*, only the second argument can accommodate the internal content of *unicorn*. Moreover, the representation in (7) corresponds to (1a). In particular if *pink unicorn* is combined with the indefinite determiner translated as existential quantifier, we obtain

$^\frown\exists x(\{pink\ (\mathtt{W}, \lambda w_2 \lambda x.\underline{unicorn}(w_2, x), x)\}$: $[x])$ as representation for the full NP, since X in (7) is identified with the object level variable $x$ contributed by the determiner (by lexical requirement of *unicorn* according to standard LRS analysis); and $x$ must also occur in the scope of the quantifier ($[x]$ after ':', separating restrictor from scope).
Now consider another adjective, *invisible*:

(8) invisible ⇝ $\mathtt{\hat{}(([\{\underline{\mathit{invisible}}\}])(W,}\ \lambda w_3 \lambda \mathtt{X.[}\ \boxed{3}\ \mathtt{(}w_3\mathtt{,\ X)],\ X))}$
(where $\boxed{3}$ is shared with the MOD|LOC|CONTENT|MAIN value of *invisible*)

(8) is combined as non-head daughter with *pink unicorn* in (7) to form *invisible pink unicorn.* In this case, $\boxed{3}$ is identified with the MAIN value of the head daughter, which is the MAIN value of *unicorn.* But in addition, according to the new clause of the SEMANTICS PRINCIPLE, (5), the internal content of the head daughter (*pink unicorn*) must be a subterm of an argument of the internal content of *invisible.* This is only possible in the scope of the two lambda abstractions of its second argument. But that means that the expression shown in the constraints in (7) must be in the scope of the two lambda expressions contributed by *invisible*, leading to what is shown in (1c). In fact, it turns out the variables $x, y$ and $z$ of (1c) are all the same variable $x$ according to the (CL)LRS constraints of the grammar, but they are either bound by different lambda abstractions ($z$, $y$) or unbound in the term (the last occurrence of $x$ in (1c)).
Let's assume alternatively that we combine *potentially* (4) with *pink* (3). In the resulting phrase, *potentially* is the non-head daughter and *pink* is the head daughter. According to the clause of the SEMANTICS PRINCIPLE above, the internal content of *pink*, which is the non-logical constant *pink*, is (a subterm of) the argument of the functor *potential*. Note that the typing of the two non-logical constants fits this requirement when *pink* is the argument of *potential*. According to the LRS PROJECTION PRINCIPLE, the external content of *potentially* becomes the internal content of *potentially pink.* Overall, this leads to the following constraint for *potentially pink*:

(9) potentially pink ⇝
$\mathtt{[\hat{}(([\{\mathit{potential}(\underline{\mathit{pink}})\}])(W,}\ \lambda w_2 \lambda \mathtt{X.[}\ \boxed{1}\ \mathtt{(}w_2\mathtt{,\ X)]\ ,\ X))]}$

The adjectival phrase *potentially pink* with the semantic representation in (9) can be combined with a noun like *unicorn* in the same way in which *pink* alone can be combined with *unicorn.* Alternatively, *potentially pink* can be combined with another adverbial modifier before it finds its nominal head (see (1d)).
A crucial feature of the analysis above is the underspecification of the functor of adjectival modification: The main relation of adjectives is potentially a subterm of the overall functor (see (3)), thus making it possible that something else takes their main relation as argument first to build a complex functor which then applies to the arguments of the adjective. This potential for combining with a modifier is preserved after a first modifier combines with an adjective, as shown in (9).

# 4 Conclusion

The analysis presented above has been implemented as a component of a larger fragment of English with CLLRS semantics in TRALE. The CLLRS implementation is entirely parallel to the LRS specification. The full paper will separate an LRS specification in AVM notation from a more complete description of implementation details in CLLRS and discuss their relationship. Moreover, it will explain the extension added to CLLRS that was necessary to allow underspecification of functors.

# References


Gallin, Daniel. 1975. *Intensional and higher-order modal logic*. Amsterdam: North-Holland.

Gamut, L.T.F. 1991. *Logic, Language and Meaning, Volume II: Intensional Logic and Logical Grammar*. University of Chicago Press.

Hahn, Michael & Frank Richter. 2015. Henkin semantis for reasoning wit natural language. *Journal of Language Modelling* 3(2). 513–568.

Kamp, Hans & Barbara Partee. 1995. Prototype Theory and Compositionality. *Cognition* 57(2). 129–91.

Kasper, Robert T. 1997. The semantics of recursive modification. Ms. Ohio State University. http://www.essex.ac.uk/linguistics/external/clmt/papers/hpsg/modification.ps.

Lahm, David. 2018. *Explorations in non-local lexical semantics. The case of* different *and plural arguments*: Goethe Universität Frankfurt dissertation.

Partee, Barbara H. 1995. Lexical Semantics and Compositionality. In Lila R. Gleitman & Mark Liberman (eds.), *An Invitation to Cognitive Science. Language*, vol. 1, 311–360. MIT Press.

Penn, Gerald & Frank Richter. 2005. The other syntax: Approaching natural language semantics through logical form composition. In Henning Christiansen, Peter Rossen Skadhauge & Jørgen Villadsen (eds.), *Constraint solving and language processing. First international workshop, CSLP 2004, Roskilde, Denmark, September 1-3, 2004, revised selected and invited papers*, vol. 3438 Lecture Notes in Computer Science, 48–73. Springer.

Richter, Frank. 2016. Categorematic unreducible polyadic quantifiers in Lexical Resource Semantics. In Doug Arnold, Miriam Butt, Berthold Crysmann, Tracy Holloway King & Stefan Müller (eds.), *Proceedings of the Joint 2016 Conference on Head-driven Phrase Structure Grammar and Lexical Functional Grammar, Polish Academy of Sciences, Warsaw, Poland*, 599–619. Stanford, CA: CSLI Publications. http://cslipublications.stanford.edu/HPSG/2016/headlex2016-richter.pdf.

Richter, Frank & Manfred Sailer. 2004. Basic Concepts of Lexical Resource Semantics. In Arnold Beckmann & Norbert Preining (eds.), *ESSLLI 2003 – Course material I*, vol. 5 Collegium Logicum, 87–143. Wien: Kurt Gödel Society.