Plural in Lexical Resource Semantics

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1 Introduction

We propose a treatment of plural semantics in Lexical Resource Semantics (LRS) (Richter & Sailer 2004, Kallmeyer & Richter 2007) by developing a lexical implementation of Sternefeld's (1998) anaylsis. Sternefeld (1998) proposes to treat pluralisation as semantic glue freely insertible into logical forms, an approach that will be refered to as *Augmented Logical Form* (ALF). ALF allows for straightforward derivations of a wide range of conceivable sentence meanings.

Free insertibility of semantic glue is of course at odds with a basic tenet of LRS, namely that every part of an utterances meaning must be contributed by some lexical element in that utterance. But combinatory system of LRS will be seen to be flexible enough to achieve very similar results by purely lexical means.

The resulting approach will also be seen to allow for a straightforward solution of an overgeneration problem of ALF. The approach predicts meanings for certain sentences that Lasersohn (1989) discusses as problem cases for (Gillon 1987). These readings can be eliminated under our proposal by ruling out more than one pluralisation of the same argument position, which can easily be achieved lexically, while implementing the same idea in ALF should require constraints on logical forms of a highly non-local nature.

The paper will proceed as follows: Section 2 gives an introduction to Sternefeld's analysis. Section 3 introduces the problematic data, which are shown to be actual problems for the ALF account in section 4. Section 5 develops the LRS analysis and section 6 concludes the paper.

2 Cumulative Predication and Augmented Logical Form

Sternefeld (1998) employs the pluralisation operations *, familiar from the work of Link, and **, and defines them as in (1-a) and (1-b).[1]

(1) a. $^*S$ is the smallest set X such that $S \subseteq X$ and $y \in X \,\&\, z \in X \Rightarrow y \cup z \in X$.
  b. $^{**}R$ is the smallest set X such that $R \subseteq X$ and $\langle u, v\rangle \in X \,\&\, \langle y, z\rangle \in X \Rightarrow \langle u \cup y, v \cup z\rangle \in X$

Basic decisions underlying the system and adhered to in the present paper are that pluralities are represented as sets of non-empty subsets of the universe of discourse D (i.e. subsets of $^*D$) and individuals are counted as pluralities by assuming $\{x\} = x$ for $x \in D$. There is a distinction between sets in the sense of elements of $^*D$ and expressions of type $\langle e, t\rangle$. In particular, all elements of $^*D$ have type e. (These assumptions are identical with those in (Schwarzschild 1996)). Sentences of the kind of (2-a), as discussed in (Scha 1981), can then be represented as in (2-b).

(2) a. 500 Dutch firms use 2000 Japanese computers.
  b. $\exists X(\mathbf{500}(X) \wedge {}^*\mathbf{DF}(X) \wedge \exists Y(\mathbf{2,000}(Y) \wedge {}^*\mathbf{JC}(Y) \wedge \langle X, Y\rangle \in {}^{**}U))$

For a sentence like (3), among others, the readings illustrated in (4) are predicted.[2]

(3) Five men lifted two pianos.

(4) a. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge \exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge \mathbf{L}(X, Y)))$
  b. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge$
   $X \in {}^*\lambda x.\exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge \mathbf{L}(x, Y)))$
  c. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge \exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge Y \in {}^*\lambda y.\mathbf{L}(X, y)))$
  d. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge \exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge X \in {}^*\lambda x.\mathbf{L}(x, Y)$
  e. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge \exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge X \in {}^*\lambda x.Y \in {}^*\lambda y.\mathbf{L}(x, y)))$
  f. $\exists X(\mathbf{5}(X) \wedge {}^*\mathbf{M}(X) \wedge \exists Y(\mathbf{2}(Y) \wedge {}^*\mathbf{P}(Y) \wedge \langle X, Y\rangle \in {}^{**}\lambda x.\lambda y.\mathbf{L}(x, y)))$

(4-a) means that five men, together, lifted two pianos, at once. Generally, an unpluralised lexical predicate is supposed to relate only objects that stand in some given relation, e.g. lifting or being lifted, *together*. (4-b) means that there

[1] These definitions do not play well with infinite sets, a technicality we ignore here.

[2] To enhance legibility, I follow Sternefeld (1998) in using $x \in S$ as a notational variant of $S(x)$ and in using uncapitalised letters for variables that are subject to a pluralisation operation. But capitalisation has no bearing on the identity of variables, i.e. X and x are merely notational variants of the same variable. Variables are (also following Sternefeld (1998)) reused 'after' pluralisation, i.e. $^*\lambda x.\phi$ typically will be applied to the variable x (then written X) again.

are five men who can, in some way, be split into subgroups, each of which, together, lifted two pinanos at once. (4-c) means that there are five men and two pianos and that the men, together, lifted the pianos, either at once or separately. (4-d) means that the five men can be divided into subgroups, all of which lifted the same two pianos at once. According to (4-e), there are five men and two pianos and subsets of the five men exist who lifted the pianos together, but perhaps not all of them at once. (4-f) means that the five men lifted the two pianos in some arbitrary configuration. All that is required is that every man took part in a lifting and that every piano was lifted.

These examples illustrate that, on the verb, the numbers and types of pluralisation operations may vary freely (while plural noun denotations always involve *). Furthermore their scope need not be the verb meaning alone but may also involve arguments of the verb, as shown by (4-b). This is achieved by the treatment of pluralisation as 'semantic glue': it is not a part of the lexical meanings of plural verbs but inserted into logical forms in appropriate places.

3 Lasersohn's criticism of (Gillon 1987)

Lasersohn (1989) points out that the account of the ambiguity of plural sentences offered by Gillon (1987) predicts that the sentences in (5) all have true readings in a situation in which each of three TAs got paid $7,000. (5-a) is true under a distributive reading and (5-b) under a collective readig in this situation. But (5-c) should not have a true reading.

(5) a. The TAs were paid exactly $7,000.
b. The TAs were paid exactly $21,000.
c. The TAs were paid exactly $14,000.

According to Gillon (1987), the readings of a sentence of the form [NP$_{plur}$VP] bijectively correspond to the *minimal covers* of the denotation of NP$_{plur}$. A minimal cover of a set X is a set $C \subseteq \mathcal{P}(X)$ that does not contain the empty set and exhausts X in the sense that every member of X is contained in at least one element of the cover. A cover is minimal if by removing a set from a minimal cover of X, something from X is also lost, i.e. not contained in any remaining member of the cover. A sentence [NP$_{plur}$VP] then has a reading, according to Gillon, "$C \subseteq$ ⟦VP⟧" for every minimal cover C of NP$_{plur}$.

If the TAs now are Alice, Bob and Ludwig, $\{\{Alice, Bob\}, \{Alice, Ludwig\}\}$ is a minimal cover. But then each element of this cover fulfills *were paid exactly $14,000* and *the TAs* thus also should, contrary to fact.

While one might guess that the non-empty intersection of the elements of the cover is to blame, allowing non-empty intersections is actually a feature of Gillon's analysis, motivated by (6).

(6) The men wrote musicals.

If *the men* is taken to refer to the set comprising Rodgers, Hammerstein and Hart, it seems that the sentence would be judged true by those familiar with these men. But none of them wrote any musicals alone and likewise no musical was written by all three of them collaboratively. The minimal cover that corresponds to the true reading of (6) is $\{\{Rodgers, Hart\}, \{Rodgers, Hammerstein\}\}$, the set of subsets of these men who collaboratively wrote musicals. This coverwhich has just the same shape as the minimal cover of the TAs that proved problematic above. Lasersohn (1989) suggests that a meaning postulate as in (7) could be used to guarantee the truth of (6) in the pertinent situation.

(7) $W(x, y) \,\&\, W(u, v) \Rightarrow W(x \cup u, y \cup v)$

This clearly defies Gillon's aim to treat (6) as ambiguous between a collaborative (i.e. simple collective) and a distributive reading and further ones that are neither fully distributive nor collective. While the scepticism expressed by Lasersohn (1989) regarding the readings licensed by Gillon's account may be justified, obliterating the distinction between collective and non-collective for the predicate *write* might be going too far.

4 Applying Sternefeld's semantics

(6) can be analysed in Sternefeld's system as in (8)

(8) ⟦the men⟧ $\in$ ***WM**

Since * need not be inserted into the logical form, the analysis (9) is also possible. In accord with what was said above about unpluralised predicates, this would only be true if the three composers had collaborated, which is not the case.

(9) $[\![\text{the men}]\!] \in \mathbf{WM}$

The sentences in (5) can receive the representations in (10).

(10) a. $\mathbf{TA} \in {}^*\lambda x.\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{7,000}(Y) \wedge Y \in {}^*\lambda y.\mathbf{PAID}(x,y))$
 b. $\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{21,000}(Y) \wedge \langle \mathbf{TA}, Y\rangle \in {}^{**}\mathbf{PAID})$
 c. $\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{14,000}(Y) \wedge \langle \mathbf{TA}, Y\rangle \in {}^{**}\mathbf{PAID})$

As things stand, all of these will be true. But (10-c) (which parallels (10-b)) only is because the meaning of *exactly* is not incorporated so far. This requires adding the requirement that Y be the unique maximal set of dollars that fulfills the scope (i.e. what follows the part stating that Y is a certain amount of dollars). This is left out here to increase readability. If this maximization operation is put in place, (10-c) will come out false in the pertinent situation. But there is a further possible rendering of (5-c), shown in (11).

(11) $\mathbf{TA} \in {}^*\lambda x.\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{14,000}(Y) \wedge \langle x, Y\rangle \in {}^{**}\mathbf{PAID})$

In (11), the expression beginning with λx denotes the set of all sets of individuals who received \$14,000 in total. Pluralising this set yields a set that contains all unions of sets of this kind, and the set **TA** is such a set. Thus it appears that (11) is a predicted reading of (5-c) that should be true in the situation considered, while in fact (5-c) is not true. This parallels the situation found in (Gillon 1987): under both accounts, finding groups who received a total of \$14,000 is enough to make (5-c) true.[3]

In Sternefeld's system, it is essential for (11) to be obtained that the subject position of PAID be pluralised twice, once using ** and then again using *. Leaving out the latter operation yields (12). It is easily seen that this formula – also a predicted reading of (5-c) under Sternefeld's approach – is not true in the given situation. It expresses that there is a sum of (exactly) \$14,000 that the TAs received, without any implications as to who of them received how much.

(12) $\mathbf{TA} \in \lambda x.\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{14,000}(Y) \wedge \langle x, Y\rangle \in {}^{**}\mathbf{PAID})$

Since the ALF framework allows for free insertion of pluralisation, it is not clear how it could rule out (11), which is just (12) with an additional pluralisation operator inserted, without imposing restrictions of a decidedly non-local nature on LF. In the next section, a solution to this problem is developed in LRS.

5 Recasting the system in Lexical Resource Semantics

The present proposal addresses the problem discussed above by capturing the essential ideas of (Sternefeld 1998) about *where* pluralisation should be insertible while taking a different stance with respect to *how* pluralisation should be inserted. The locus of pluralisation will be strictly lexical. At the same time, pluralisation can occur in different places, not directly tied to the core meaning of the verb, i.e. with material contributed by other expressions intervening. This is achieved using Lexical Resource Semantics.

5.1 Lexical Resource Semantics

LRS (Richter & Sailer 2004, Kallmeyer & Richter 2007) is a flavour of underspecified semantics that makes use of the descriptive means of HPSG and uses its constraint language, which is assumed here to be Relational Speciate Reentrant Language (RSRL)(Richter 2004), as the locus of underspecification. Disregarding the treatment of local semantics (Sailer 2004), the semantic representation connected to a sign (i.e. a syntactic object) is an object of a sort *lrs* to which three features are appropriate: INCONT, EXCONT and PARTS. For each word, the value of the INCONT feature is this word's scopally lowest semantic contribution, i.e. that part of its semantics over which every other

[3] In a reply to (Lasersohn 1989), Gillon (1990) describes a situation in which two departments employ two TAs each. \$14,000 are paid for each pair of TAs, which they may divide among themselves as they deem fit. It then seems that (i-a) would be judged true. But – disregarding the role of "their" and ignoring the temporal modifier – this can be formalised as in (i-b) under the present approach.

(i) a. The TAs were paid their \$14,000 last year.
 b. $\mathbf{TA} \in {}^*\lambda x.\exists Y({}^*\mathbf{\$}(Y) \wedge \mathbf{14,000}(Y) \wedge \mathbf{PAID}(x, Y))$

Since each pair of TAs was paid as a team, the sets of respective team members will each be related to \$14,000, but the individual members will not. Under these circumstances, (i-b) is true.

operator in the word's maximal projection takes scope. The EXCONT value roughly corresponds to the meaning of the maximal projection of a word. Both INCONT and EXCONT project strictly along head lines.

The value of PARTS is a list that contains the lexical resources that a sign contributes. For words, they are lexically specified. For phrases, they always are the concatenation of the PARTS lists of the daughters. In an utterance, i.e. an unembedded sign, each element of the PARTS list must occur in the EXCONT value and everything that occurs in it must be on the PARTS list. The EXCONT value of an utterance is regarded as its meaning.

The values of the three attributes are related by a small set of core constraints. In addition to these, the SEMANTICS PRINCIPLE provides further more or less construction-specific constraints that ensure that they are also related in a way that correctly represents how meaning is composed in different syntactic configurations. For example, in *every dog*, the INCONT of *dog*, $D(x)$, must be a subexpression of the restrictor of the universal quantifier. Since the NP contains no further material that combines with *dog*, this will actually result in identity. Similarly, if a quantified NP combines with a verb, the verb must be found in the NP quantifier's scope. *Every dog barks* thus receives the desired interpretation $\forall x(D(x), B(x))$

5.2 The analysis

Almost everything that needs to happen for the present approach to work happens on the PARTS list. Manipulating this list gives the opportunity to furnish lexical items with semantic material that must occur in the utterance they are used in, but the places in which this material can occur are not subject to any restriction that is not explicitly stated.

The general shape of the LRS semantics of *lift* is as follows.[4]

$$\begin{bmatrix} \text{INCONT} & \boxed{1}\,\mathbf{L}(x,y) \\ \text{EXCONT} & [\boxed{1}] \\ \text{PARTS} & \langle \boxed{1}, (\mathbf{L}y), \mathbf{L} \rangle \oplus \boxed{P} \end{bmatrix}$$

The PARTS list contains the INCONT and those of its subexpressions that *lift* needs to contribute as lexical resources (the variables originate from the NPs). In addition, it contains all elements of the list $\boxed{P}$, which is where pluralisation operations enter. $\boxed{P}$ is subject to the following condition.[5]

(13) Every variable that is associated with a plural nominal argument of the verb may be subject to at most one pluralisation operation on $\boxed{P}$.

Formalising this constraint in RSRL is a tedious but straightforward task. Given (13), a variable x_i, $1 \leq i \leq n$, is subject to a pluralisation operation on $\boxed{P}$ if $\boxed{P}$ contains ${}^{*n}\lambda x_1 \ldots \lambda x_n.\phi$.[6] It is the restriction (13) that will prevent the unwanted reading of Lasersohn's example sentence. Since at most one pluralisation is allowed, the kind of double pluralisation that was identified as problematic above is ruled out.

$\boxed{P}$ may be empty. This will give the reading of (3) in (4-a). Five men jointly lifted two pianos at once. Further admissible lists are shown in (14).[7]

(14)
a. $\langle ({}^{*}\lambda x.[\boxed{1}])(x), \ldots \rangle$
b. $\langle ({}^{*}\lambda y.[\boxed{1}])(y), \ldots \rangle$
c. $\langle ({}^{*}\lambda x.[\boxed{1}])(x), ({}^{*}\lambda y.[\boxed{1}])(y), \ldots \rangle$
d. $\langle ({}^{**}\lambda x.\lambda y.[\boxed{1}])(x, y), \ldots \rangle$

It is easily seen that all lists in (14) conform to (13): In (14-a), only x is subject to pluralisation and only pluralised once. The same is true for y regarding list (14-b). In (14-c), both are pluralised once, independently of each other. In (14-d), both variables are pluralised together once using **.

Importantly, now, $[\boxed{1}]$ in the expressions above may stand for any expression that has $\boxed{1}$ (the verb's INCONT) as a subexpression.[8] All that is thus said about the scope of the pluralisations is that they contain $L(x, y)$. Unless

[4]Tags like $\boxed{1}$ are variables used to indicate token identity. So $\boxed{1}$ in the entry for *lift* always denotes the expression $\mathbf{L}(x, y)$. $[\boxed{1}]$ may be any expression that contains $\boxed{1}$.

[5]Readers have raised questions regarding independent motivation of this constraint. But I think this makes the possibility of repeated pluralisation, as in ALF, the null hypothesis. But since being allowed to enrich meanings with unlimited amounts of material is not the established standard in semantics I fail to see any better motivation for allowing multiple pluralisations of the same argument than for not doing so, especially if the latter approach makes more accurate predictions.

[6]I.e. an operator of n stars applied to an n-place relation. In this paper, $n \leq 2$.

[7]The dots on the list stand for lexical resources that are needed in addition to those explicitly shown (namely parts of these).

[8]Each occurence of $[\boxed{1}]$, even on the same list, may stand for a different such expression.

constrained further, they may thus occur anywhere in the meaning representation of a complete sentence, provided that the types fit. While the number of possible pluralisations is thus limited and while they enter into the semantics from the lexicon, their distribution will in other respects be as under the ALF approach.

As remarked above, plural nouns are always pluralised using *. For *pianos*, e.g., the semantics is as follows.[9]

$$\begin{bmatrix} \textsc{incont} & \boxed{3}\,^*\mathbf{P}(X) \\ \textsc{excont} & \boxed{2}\,\exists X\,([\boxed{3}], \boxed{4}) \\ \textsc{parts} & \langle \boxed{2}, \boxed{3}, {}^*\mathbf{P}, \mathbf{P}, X \rangle \end{bmatrix}$$

The combinatorial behaviour of plural NPs is as dictated by the SEMANTICS PRINCIPLE and discussed above: the INCONT of a verbal projection they combine with needs to be a part of their scope, i.e. $\boxed{4}$ above.

The system can be illustrated by a comparison of (4-b) and (4-d). These are only distinguished by the place in which x is pluralised. The variable y is not pluralised. As required by the SEMANTICS PRINCIPLE, $\boxed{1}$ is in the scope of both quantifiers in both (4-b) and (4-d). Since only x is pluralised, the pluralisation list (14-a) needs to be assumed in both cases, but with different expressions as values of $[\boxed{1}]$. In (4-b), this expression includes the expression $\exists Y \ldots$, in (4-d), it is identical with $\boxed{1}$. Both conform to the requirement of (14-a) that $\boxed{1}$ be in the scope of the pluralisation operator. Since both readings fulfill all pertinent constraints, they both are predicted to be possible, as desired.

The problematic reading (11) of (5-c) is ruled out since it would require a list like (15) in order for the two pluralisations found in that formula to be available as lexical resources.

(15) $\quad * \ \langle \boxed{1}, ({}^*\lambda x.[\boxed{1}])(x), ({}^{**}\lambda x.\lambda y.[\boxed{1}])(x, y), \ldots \rangle$

But since x is pluralised twice, (15) violates (13) and is hence not a possible pluralisation list. (12) only requires list (14-d) and thus remains a possible reading.

6 Conclusion

It was argued that (Sternefeld 1998) suffers from the same problem of overgeneration that Lasersohn (1989) points out with respect to (Gillon 1987). The source of the problem was identified as inherent to the framework of Augmented Logical Form that Sternefeld (1998) employs. The framework allows for more than one pluralisation of a verbal argument position, and without this possibility the overgeneration disappears. A lexicalist reformulation of Sternefeld's system was offered that puts verbal argument pluralisation into the lexical semantics of the verb and shown to allow for restricting the possible pluralisations on any argument position to one. The account was developed in Lexical Resource Semantics, thereby also offering the first treatment of plural semantics in this framework.

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[9] Since indefinite plural NPs do not occur with an article in English, the quantifier is assumed to be a direct contribution of the noun. For cardinals and other plural quantifiers, an analysis as intersective adjectives is intended. Nothing of consequence hinges on these preliminary assumptions.