Chapter 1

Underspecified Treatment of Verb Phrase Ellipsis

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Abstract. This paper deals with the underspecified semantic representation of ellipsis and its resolution. We present an analysis to explain the distribution of *strict* and *sloppy* readings in the interaction of verb phrase ellipsis and anaphora. The analysis is integrated into a framework that enables a uniform and underspecified treatment of scope, anaphora and VPE.

1 Introduction

Natural language is known for the ambiguity of its expressions. Traditional theories of natural language semantics involve mapping natural language utterances into expressions of an unambiguous representation language (logical formulas) (e.g., [Montague,1974]). Within these theories, interpreting an ambiguous utterance is typically modeled by choosing the intended interpretation from a plurality of possible ones. This generate–and–test method is neither computationally feasible nor cognitively plausible [Pinkal,1996]. In the last few years, underspecified semantic representation has received increasing attention, motivated almost exclusively by computational considerations about processing natural language semantics. The aim of underspecified semantic representation is to produce compact representations of the set of possible readings of a discourse.

When anaphora and quantifiers are involved in VPE, the problem of ambiguities can be very complex because the interpretation of VPE must obey a certain parallelism between the antecedent clause and the elliptical expression. Although recently a lot of approaches to semantic underspecification (e.g., [Alshawi & Crouch,1992, Reyle,1993, Copestake et al.,1995, Egg & Lebeth,1995, Bos,1996, Pinkal,1996]) as well as ellipsis resolution (e.g., [Hobbs & Kehler,1997, Shieber et al.,1996a, Gardent & Kohlhase,1996, Kehler,1995, Dalrymple et al.,1991]) have emerged in computational linguistics, few of them are designed to treat both problems uniformly. It is still a challenge to develop a semantic underspecification formalism which enables a simple, integrated, and uniform treatment of scope, parallelism and anaphora. [Niehren et al.,1997] propose a framework of context unification (CU) which deals with phenomena of quantifier scope, VPE and their interaction in a uniform and underspecified way. However, CU does not cope with anaphora. The Constraint Language over Lambda Structures (CLLS) [Egg et al.,1998] extends and improves the language of CU and integrates our ellipsis analysis in a straightforward way. As an additional advantage, CLLS has reached a coverage of scope, anaphora and VPE.

Discussions about anaphora in VPE usually begin with the observation that there is an ambiguity in the interpretation of the elided pronoun in an elliptical construction such as (1.1):

(1.1) John$_1$ likes his$_1$ mother, and Bill does too.

The stranded auxiliary in the second clause (the *target* clause) indicates the elision of a VP. A representation for the elided VP must be recovered from the representation of another clause, in this case, the first clause (the *source* clause). The two subjects 'John' and 'Bill' are *parallel elements.* Parallel elements are constituents in the source clause and their overt parallel counterparts in the target clause. Under the reading in which the pronoun 'his' refers to the source parallel element 'John', the target clause can be understood either as Bill likes *John's* mother – the *strict* reading – or Bill likes *Bill*'s mother – the *sloppy* reading.

However, not all sentences are as simple as (1.1). There are a series of problematic cases of strict and sloppy ambiguities mentioned in the literature, such as the many-pronouns-puzzle [Dahl,1974]. We argue that the strict and sloppy readings arise from the interaction of anaphoric links and the parallelism requirement in ellipsis. We integrate our ellipsis analysis into the framework of CLLS. The constraint language of CLLS is a first–order language for semantic underspecification. It is sufficiently expressive for an integrated treatment of quantifier scope, anaphora and ellipsis. We illustrate CLLS at a benchmark example (1.2) for the interaction of scope, anaphora, and VPE.

(1.2) Mary read a book she liked before Sue did.

The paper is organized as follows. First, we present our analysis for VPE and anaphora. In section 3 we illustrate the application of CLLS to (1.2). In section 4 we close off the paper by summing off the open questions for the future research.

2 Analysis

The parallelism requirement in our analysis is that an elided pronoun can be either linked to its parallel pronoun in the source clause (referential parallelism) or be linked in a structurally parallel way (structural parallelism). The linking relation describes the referential dependence between an anaphoric element and its antecedent. The determination of linking relations in our analysis is as same as defined in [Kehler,1995]. That is there is a correspondence between binding relations in syntactic representations [Chomsky,1981] and linking relations in semantic representations. The definition of *linking* is given as follows.

> A referential dependent element is linked to another element which binds it most immediately in the syntax. If there is no binding available, then it is linked to the most salient discourse referent.

For example (1.1), the pronoun 'his' is linked to the subject 'John' in the semantic representations since 'his' is bound by 'John' most immediately in the syntax (There is no other binder available.). The linking relation is graphically represented as an arrow pointing from the pronoun (see (1.3)).

(1.3) John$_1$ likes his$_1$ mother.

Given such a link in the source clause, the elided pronoun in the target clause can be either linked to its parallel pronoun in the source clause to have the same referential value, visualized in (1.4), or be linked to the target parallel element 'Bill' to establish a link which is structurally parallel to the link in the source clause, given in (1.5). In (1.4) the elided pronoun refers to the source pronoun which refers to 'John', yielding the strict interpretation. In (1.5) the elided pronoun refers to the target parallel element 'Bill', receiving the sloppy interpretation.

(1.4)
John$_1$ likes his$_1$ mother.
Bill$_2$ likes his$_1$ mother

(1.5)
John$_1$ likes his$_1$ mother.
Bill$_2$ likes his$_2$ mother

At example (1.1), we have shown that our analysis is suitable to explain the basic case of the strict and sloppy ambiguities. One might expect that there are 2^N readings for the target clause for examples in which there are N pronouns in the source clause which are coreferent with the source parallel element. However, [Dahl,1974] noticed that example (1.6) has only three readings, not four (2^2). Hence, the reading (1.7) in which the first elided pronoun has a strict reading whereas the second elided pronoun has a sloppy reading is *missing*.

(1.6) John$_1$ said that he$_1$ liked his$_1$ mother, and Bill did too.

(1.7) Bill said that *John* liked *Bill*'s mother.

Our analysis accounts for (1.6). In the source clause, the second pronoun 'his' is linked to the first pronoun 'he', rather to the subject 'John' since 'he' binds 'his' most immediately in the syntax. In (1.8), the linking chain in the source clause (formed by the two connected links) does not allow the combination of links in the target clause since the link between 'his' and 'Bill' in the target clause does not have a parallel link in the source clause, not obeying the parallelism theorem. Hence it follows that the reading (1.7) resulting from (1.8) is ruled out in our analysis.

(1.8) $*$ John$_1$ said he$_1$ liked his$_1$ mother.
Bill$_2$ said he$_1$ liked his$_2$ mother.

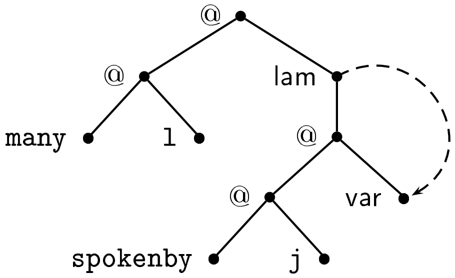
The linking chain and the parallelism requirement is the best explanation for the strict and sloppy ambiguities in examples containing many pronouns. The basic idea underlying our analysis agrees with the proposals made in [Kehler,1995, Hobbs & Kehler,1997] and covers a series of other benchmark puzzles such as the cascaded ellipsis and the five-reading sentence. However, the frameworks used in the two approaches cannot treat the ellipsis problem in an underspecified way and they cannot be extended straightforwardly to deal with other semantically underspecified phenomena, such as the scope ambiguities. Therefore, it is an advantage of our approach to integrate our ellipsis analysis into a general underspecification mechanism which covers the interaction of scope, anaphora and parallelism.

3 Application of CLLS

A λ-structure is a tree structure extended by two additional relations (the binding relations for lambda bindings and linking relations for anaphoric links) [Egg et al.,1998]. We represent λ-structures as graphs. Every λ-structure characterizes a unique λ-term or a logical formula up to consistent renaming of bound variables (α-equality). E.g., the λ-structure characterizes the HOL-formula (1.9).

(1.9) $(\mathtt{many}(\mathtt{language}))(\lambda\mathtt{x}.\mathtt{spokenby}(\mathtt{john})(\mathtt{x}))$

(1.10)



Two things are important here: the label '@' represents explicitly the operation of function application, and the binding of the variable x by the λ-operator λx is represented by an explicit *binding relation* λ between two nodes, labeled as var and lam. As the binding relation is explicit, the variable and the binder need not be given a name or index such as x.

A constraint is an underspecified description of a λ structure. We can fully describe the above λ structure (1.10) by means of constraints. We represent the constraints of the λ structures as graphs as well. It is important to distinguish the graphs for λ structures from those as constraints which are seen as descriptions of the λ structures that satisfy them. There are various types of constraints. They are dominance constraints, binding constraints, linking constraints and parallelism constraints. The parallelism constraint describes the similarity between two λ structures. We analyze elliptical constructions by means of the parallelism constraint of the form

(1.11) $X_s/X_{sp}{\sim}X_t/X_{tp}$

which has the intuitive meaning that the semantics X_s of the source clause is *similar* to the semantics X_t of the elliptical target clause, *up-to* the exceptions X_{sp} and X_{tp}, which are the semantic representations of the parallel elements.

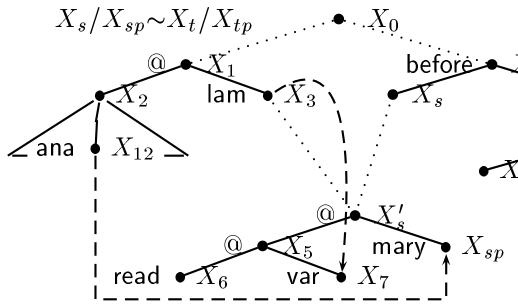
Our analysis is integrated into CLLS in the following way: Linking relations between the semantics of pronouns and their antecedents are expressed by linking constraints; the options for anaphoric links of the elided pronouns are spelt out in the resolution algorithm for solving the interaction of linking constraints and parallelism constraint. In addition, we use dominance constraints and binding constraints to describe semantically underspecified information, such as scope ambiguities. The semantic representation of VPE is a union of the constraint sets obtained by interpreting source clause and target clause independently of each other plus the parallelism constraint. Its resolution involves solving the constraints.

In the following, we will illustrate the application of CLLS to the complex case of the interaction of scope, anaphora, and ellipsis, namely (1.2). In (1.2), repeated as (1.12), both anaphora and quantification interact with ellipsis.

(1.12) Mary read a book she liked before Sue did.

(1.12) has three readings (see e.g. [Crouch,1995]). In the first, the indefinite NP 'a book she liked' takes wide scope over both clauses (a particular book liked by Mary is read by both Mary and Sue). In the two others, the operator 'before' outscopes the indefinite NP. The two options result from the two possibilities of reconstructing the pronoun 'she' in the ellipsis interpretation, viz., 'strict' (both read some book that Mary liked) and 'sloppy' (each read some book she liked herself).

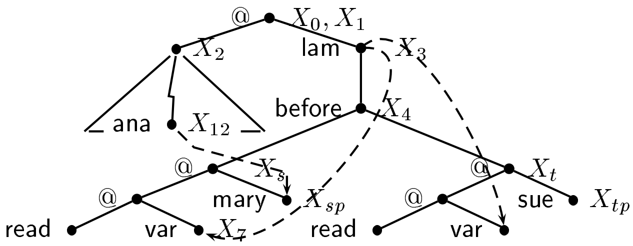
(1.13)



The constraint for (1.12), displayed in (1.13), is an underspecified representation of the above three readings. X_s and X_t represent the semantics of the source and the target clause, while X_{sp} and X_{tp} stand for the semantics of the parallel elements ('Mary' and 'Sue') respectively. For readability, we represent the semantics of the complex NP 'a book she liked' by a triangle dominated by X_2, which only makes the anaphoric content X_{12} of the pronoun 'she' within the NP explicit. The anaphoric relationship between the pronoun 'she' and 'Mary' is represented by the linking relation between X_{12} and X_{sp}. X_e represents the semantics of the elided part of the target clause. We represent dominance constraints graphically as dotted lines. E.g., in (1.13), both X_1 and X_4 are dominated by X_0. This means that the scope order between the indefinite NP and the operator 'before' is undetermined. The binding relation between X_3 and X_7 plus the dominance relation between X_3 and X_s' represents the scope underspecification of the indefinite NP.

The first reading, with the NP taking wide scope, results when the relative scope between X_1 and X_4 is resolved such that X_1 dominates X_4. The corresponding solution of the constraint is visualized in (1.14).

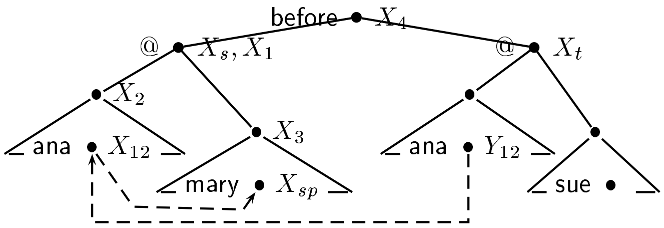
(1.14)



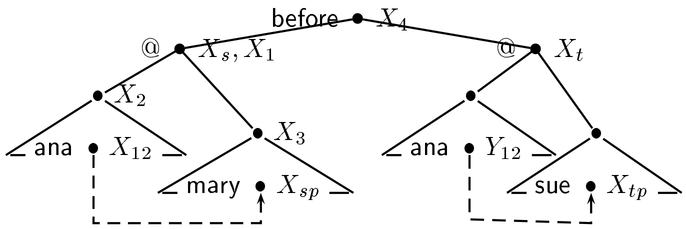
The similarity constraint $X_s/X_{sp}{\sim}X_t/X_{tp}$ is satisfied in the solution because the node X_t dominates a tree that is a copy of the tree dominated by X_s. In particular, it contains a node labeled by var, which has to be similar to X_7, and therefore must be λ bound to X_3 too.

The other possible scoping is for X_4 to dominate X_1. The two solutions this gives rise to are drawn in (1.15) and (1.16). Here X_1 and the interpretation of the indefinite NP directly below enter into the parallelism as a whole, as these nodes lie below the source node X_s. Thus, there are two anaphoric nodes: X_{12} in the source and its 'copy' Y_{12} in the target semantics. For the copy to be *similar* to X_{12} it can either have a link to X_{12} to have a same referential value (strict reading, see (1.15)) or a link to X_{tp} that is structurally parallel to the link from X_{12} to X_{sp}, and hence leads to the node of the parallel element 'Sue' (sloppy reading, see (1.16)).

(1.15)



(1.16)



4 Conclusion

In this paper, we provided an analysis of VPE and anaphora. We have shown that our analysis explains the complicated behavior of the elliptical constructions which many ellipsis analyses fail to deal with. Our analysis has reached the same coverage as the approaches of [Kehler,1995, Hobbs & Kehler,1997]. However, [Kehler,1995] and [Hobbs & Kehler,1997] do not treat the ambiguities in an underspecified way. In addition, they do not include a treatment of scope ambiguities so far. We integrated our analysis into CLLS which extends the coverage of the approach of [Niehren et al.,1997] to include anaphora and VPE. The framework of CLLS reaches comparable coverage as the approaches of [Shieber et al.,1996b] and [Crouch,1995]. Compared to them, CLLS allows a uniform and transparent treatment of underspecification phenomena. Moreover, CLLS supports efficient constraint-based semantic processing. In CLLS semantic processing can be modeled by monotonic extensions of a constraint store. Since the concept of a monotonic constraint store underlies the paradigm of concurrent constraint programming [Saraswat et al.,1991, Smolka,1994], we can implement CLLS with high-level concurrent constraint programming techniques [Smolka,1995].

Finally, we identify some points of future research suggested by the proposal presented here. The first point is that we would investigate a special type of the interaction of VPE and anaphora, namely, the interaction of VPE and reflexives [Hestvik,1993]. We are intended to find out the different behaviors between the anaphoric pronouns and reflexives in VPE and hope to be able to extend our analysis to deal with them. Let's consider two simple examples about VPE and reflexives.

(1.17) John hit himself before Peter did.

(1.18) John hit himself, and Peter did too.

In (1.17), the reflexive gives rise both a strict and a sloppy reading for the target clause. It behaves similarly as a pronoun in VPE. However, in (1.18) the target clause has only a sloppy reading. It is easy to see that the distribution of the strict and sloppy readings of reflexives is different from that of the pronouns in some way.

The second point is the question of how to integrate CLLS into a natural language processing system. In particular, we are aimed to apply CLLS to deal with incomplete utterances as given in spoken language [Pinkal,1996], although this research area is still regarded as a major obstacle for the further developments in computational linguistics.

Bibliography

[Alshawi & Crouch,1992] H. Alshawi and R. Crouch. 1992. Monotonic semantic interpretation. In *Proceedings 30th Annual Meeting of the Association for Computational Linguistics*, 32–38.

[Bos,1996] Johan Bos. 1996. Predicate Logic Unplugged. In Paul Dekker and Martin Stokhof, editors, *Proceedings of the Tenth Amsterdam Colloquium*, 133–143, ILLC/Department of Philosophy, University of Amsterdam.

[Chomsky,1981] Noam Chomsky. 1981. *Lectures in Government and Binding.* Foris, Dordrecht.

[Copestake et al.,1995] A. Copestake, D. Flickinger, R. Malouf, S. Riehemann, and I. Sag. 1995. Translation using minimal recursion semantics. In *Proceedings of the Sixth International Conference on Theoretical and Methodological Issues in Machine Translation.* University of Leuven, Belgium.

[Crouch,1995] Richard Crouch. 1995. Ellipsis and quantification: A substitutional approach. In *Proceedings EACL'95*, 229–236, Dublin.

[Dahl,1974] Östen Dahl. 1974. 'how to open a sentence: Abstraction in natural language'. *Logical Grammar Reports.*

[Dalrymple et al.,1991] Mary Dalrymple, Stuart Shieber, and Fernando Pereira. 1991. Ellipsis and higher-order unification. *Linguistics and Philosophy*, 14:399–452.

[Egg & Lebeth,1995] Markus Egg and K. Lebeth. 1995. Semantic underspecification and modifier attachment ambiguities. In J. Kilbury and R. Wiese, editors, *Integrative Ansätze in der Computerlinguistik*, 19–24. Düsseldorf, Seminar für Allgemeine Sprachwissenschaft.

[Egg et al.,1998] Markus Egg, Joachim Niehren, Peter Ruhrberg, and Feiyu Xu. 1998. Constraints over lambda-structures in semantic underspecification. accepted by COLING 1998.

[Gardent & Kohlhase,1996] Claire Gardent and Michael Kohlhase. 1996. Higher-order coloured unification and natural languages semantics. In *Proceedings of the 34th Annual Meeting of the Assocation for Computational Linguistics.* Santa Cruz.

[Hestvik,1993] Arild Hestvik. 1993. Strict reflexives and the subordination effect. In S. Berman and A. Hestvik, editors, *Proceedings of the Stuttgart Workshop on Ellipsis: Arbeitspapiere des Sonderforschungsbereich 340, Bericht Nr. 29-1992, SFB 340.* University of Stuttgart and University of Tübingen and IBM Germany.

[Hobbs & Kehler,1997] Jerry R Hobbs and Andrew Kehler. 1997. A theory of parallelism and the case of VP-Ellipsis. In *Proceedings of ACL-1997*, 394–401.

[Kehler,1995] Andrew Kehler. 1995. *Interpreting Cohesive Forms in the Context of Discourse Inference.* Ph.D. thesis, Harvard University, Center for Research in Computing Technology, Cambridge, Massachusetts.

[Montague,1974] R Montague. 1974. The proper treatment of quantification in ordinary english. In R. Thomason, editor, *Formal Philosophy. Selected Papers of Richard Montague*, 247–271. Yale University Press, New Haven and London.

[Niehren et al.,1997] Joachim Niehren, Manfred Pinkal, and Peter Ruhrberg. 1997. A uniform approach to underspecification and parallelism. In *Proceedings of ACL-1997.*

[Pinkal,1996] Manfred Pinkal. 1996. Radical Underspecification. In Paul Dekker and Martin Stokhof, editors, *Proceedings of the Tenth Amsterdam Colloquium*, 587–606, ILLC/Department of Philosophy, University of Amsterdam.

[Reyle,1993] Uwe Reyle. 1993. Dealing with ambiguities by underspecification: construction, representation and deduction. *Journal of Semantics*, 10:123–179.

[Saraswat et al.,1991] Vijay A. Saraswat, Martin Rinard, and Prakash Panangaden. 1991. Semantic foundations of concurrent constraint programming. In *ACM Symposium on Principles of Programming Languages*, 333–352. ACM Press, New York.

[Shieber et al.,1996a] Stuart Shieber, Fernando Pereira, and Mary Dalrymple. 1996a. Interaction of scope and ellipsis. *Linguistics and Philosophy*, 19:527–552.

[Shieber et al.,1996b] Stuart Shieber, Fernando Pereira, and Mary Dalrymple. 1996b. Interaction of scope and ellipsis. *Linguistics and Philosophy*, 19:527–552.

[Smolka,1994] Gert Smolka. 1994. The definition of kernel Oz. Dfki oz documentation series, German Research Center for Artificial Intelligence (DFKI), Saarbrücken.

[Smolka,1995] Gert Smolka. 1995. The Oz Programming Model. In Jan van Leeuwen, editor, *Computer Science Today*, 324–343. Springer-Verlag, Berlin.