Language, Information and Computation(PACLIC 11), 1996, 53-62

Underspecified Japanese Semantics in a Machine Translation System*

Björn Gambäck Christian Lieske Yoshiki Mori

Department of Computational Linguistics
University of the Saarland
Postfach 151150
D-66041 Saarbrücken, Germany
e-mail: {gam,lieske,mori}@coli.uni-sb.de

Abstract

Semantic representations which are underspecified with respect to, for example, scope, have recently attracted much attention. Most research in this area has focused on treating English language phenomena in a theoretical fashion. Our paper deviates from this twofold: We take Japanese as the language of our investigations and describe how our ideas about underspecified Japanese semantics (e.g., on modality adverbs) have been implemented in a spoken-language machine translation system.

1 Introduction

Natural language expressions are inherently ambiguous. Ambiguities can be caused, for example, by the fact that one of the words used does not have a unique meaning, that more than one syntactic structure may be assigned to the expression, that the scopal relations are not clear, etc. Regardless of the cause, ambiguities are problematic for Natural Language Processing, one of the problems being that they decrease processing efficiency: usually all of the possible interpretations have to be assumed to be right until hard facts prove the contrary. Unfortunately, this can oftentimes not be decided on until after a lot of processing already has been done.

A way around this dilemma is to have a common representation for *all* of the possible interpretations of an ambiguous expression, as in (Alshawi *et al.*, 1992; Kameyama, 1995). Recent research (Reyle, 1993; Bos, 1995; Pinkal, 1995; Cooper *et al.*, 1996) has used the term *underspecification* to describe this idea: One does not use representations (we will assume formulæ of a certain logic in what follows) that encode one single concrete interpretation but a *set* of interpretations.

One prominent area where underspecification can be used, namely for leaving possible scopal domains undecided on, can be explicated with the Japanese sentence in (1): Here, the scope of the focus particle '*dake*' ('*only*') cannot be determined. Thus, all of the

*This work was funded by the German Federal Ministry of Education, Science, Research, and Technology (BMBF) under grant 01 IV 101 R. We are grateful to Johan Bos, Karsten Worm, and Manfred Pinkal for comments and to Julia Heine, Daniela Kurz, and Feiyu Xu for their work on the lexicon.

translations given in (2) are viable, the expression is ambiguous and an underspecified representation is called for.

(1)	*Yamada*	*kara*	*kari*	*ta*	*dake*	*desu*
	Yamada	from	borrow	past	only	cop.+pres.

(2) I only *borrowed it from Yamada.*
I only borrowed it *from Yamada.*
I only *borrowed* it from Yamada.

The main reason for introducing the underspecified representations has been processing efficiency. For us, however, using underspecified representations has another motivation. In this paper we will discuss underspecification within the semantic formalism of the machine translation (MT) system Verbmobil, a system where the transfer from source language expressions into target language expressions takes place at the (compositional) semantic level. Since ambiguities on the side of the source language often also appear on the side of the target language, resolution of ambiguity is not always necessary.

In the rest of the paper, we will discuss these matters in greater detail. First, Section 2 gives some more examples of semantic underspefication in general and some specific to Japanese in particular. Section 3 describes the Verbmobil project. In Section 4, the semantic formalism which we use is introduced together with a short formal definition. To make things more concrete, Section 5 then discusses how the actual implementation has been made and exemplify this with showing the underspecified representations for several phenomena. Finally, Section 6 sums up the discussion and points to some areas of further research.

2 Phenomena suitable for underspecification

Most of the present work in the field has concentrated on the underspecification of scopal and lexical ambiguities. Of course, several other phenomena are equally well suited for underspecification. Here we will adopt an ordering of these phenomena according to three different "levels" based on the structural properties of the ambiguity, that is, an ordering following the one of (Pinkal, 1995). According to this ordering, phenomena belonging to the first level are those which are confined to a small, local part of an otherwise uniquely defined semantic structure. The main example of such a phenomenon is the case of lexical ambiguity. Another example is the referential ambiguity introduced by the anaphoric or deictic uses of pronouns.

The second level of underspecification refers to global ambiguities. The primary example is scopal ambiguities. In addition, for example ambiguities introduced by collective-distributive readings belong to this group. These phenomena are the ones that most of the present work in the area aim at treating, and that mainly at the representational level. Several representations for this type of underspecification have thus been introduced, for example, Quasi Logical Form, QLF (Alshawi and Crouch, 1992) and Underspecified Discourse Representation Theory, UDRT (Reyle, 1993). Our representation for tackling this type of phenomena, Language for Underspecified Discourse representations, LUD, was introduced in (Bos *et al.*, 1996). In the present paper, we will only give a brief account of it (Section 4).

Finally, (Pinkal, 1995) discusses a third level of underspecified semantic phenomena. These are the ones caused by ambiguous syntactic information (e.g., PP-attachment), or even by incoherent non-semantic information. An example is number disagreement introducing a range of different possible interpretations, matching the possible correct agreement cases. In the rest of this section, however, we will concentrate on a couple of phenomena belonging to the second level, but which we believe are rather specific to Japanese and which have so far not been addressed in the literature.

2.1 Japanese noun phrases

Unlike many European languages, Japanese does not grammaticize definiteness in noun phrases. Nevertheless, we think that it makes sense to talk about scope bearing elements in NPs (i.e., we do not consider marking of indefiniteness being a prerequisite for talking about scope). We thus assume an opaque scope bearing element in the Japanese NPs, similar to the markers of definiteness/indefiniteness found in many other languages. (3) shows that this is viable: The scopal relation of '*minna*' and the unrealized scope bearing element of '*hon*' is ambiguous when the latter is interpreted as indefinite. In (4), an ad-nominal quantification introduced by '*iroiro*' is interwined with the adverbial quantification given by '*itsumo*'.

(3)	*minna*	*wa*	*Hanako*	*ni*	*hon*	*o*	*katta*
	everybody	topic	Hanako	dat	book	acc	buy+past

Everybody bought (a) book for Hanako.

(4)	*itsumo*	*iroiro*	*kaigi*	*ga*	*hait*	*te*	*ori*	*masu*
	always	various	conference	nom	be-put-in	part	asp	hon+pres

Various conferences are scheduled in every time-slot.

The above examples are truly ambiguous, but it should be noted that the actual word order, or the use of topic and focus particles, often supports the disambiguation of cases similar to these. That is, often possible readings are ruled out on structural grounds alone.

2.2 Modality adverbs

Another area where we assume ambiguity and accordingly underspecified representations for Japanese is modality adverbs. An example is given in (5). Here, '*tabun*' expresses an epistemic modal and '*ichioo*' the intention for discharging some obligation (i.e., an attitudial modality) which holds temporarily.

(5)	*ichioo*	*tabun*	*denwa*	*shi*	*masu*
	just	possibly	call	make	hon+pres

(6) It is just possible that I will call you.
It is possible that I just will call you.

The ambiguity arises from the fact that '*tabun*' may outscope '*ichioo*' or vice versa. The English equivalent (6) demonstrates the ambiguity (with '*possible*' and '*just*' being the corresponding adverbs). Neglecting the temporal aspect (which can be translated as "*for the time being*"), we get two readings. In the first reading, the epistemic modal outscopes the attitudinal modality bound to the speech time. In the second reading, it is the other way around. Note that Japanese allows for splitting the tense for the modality from the tense of the event described by the kernel clause.

3 Verbmobil

The Verbmobil machine translation system (Kay *et al.*, 1994; Wahlster, 1993), funded by the German Federal Ministry of Research and Technology (BMBF), combines speech technology with machine translation techniques. The objective of the first four years of the project has been to produce a device operating almost in real-time, providing English translations in a dialogue setting where the input may be either German or Japanese. An important feature of the system is that it accepts spoken utterances containing phenomena found in spontaneous speech (e.g., hesitations and ellipsis). Requirements that help to achieve this are the restriction to the domain of business appointment scheduling dialogues and the explicit invocation of the translation process by means of a mouse click.

In the 1996 version of Verbmobil, the so-called *Forschungsprototyp*, the overall functionality was realized by the complex interaction of some 50 components, developed by academic institutions and industry from Germany, the United States and Japan. On the source language side (German and Japanese), there are components for speech recognition, (interleaved) syntactic and semantic analysis, semantic evaluation/pragmatic analysis, as well as for dialogue management (when the users speak English, the process is less complex since only keyword spotting takes place to ensure proper recording of the dialogue history). On the target language side (English), generation and speech synthesis are carried out. In between, there is a transfer component that maps semantic representations of source language expressions onto semantic representations of target language expressions.

Our component of Verbmobil, falls into the realm of syntactic-semantic analysis. It interleaves syntactic and semantic processing, and consists of four parts: a parser that works on word lattices, German and Japanese grammars written in the Trace and Unification Grammar formalism (TUG) (Block and Schachtl, 1992), and a compiler that creates highly efficient code for the parser from the grammars.

The German grammar of our component has been developed in close collaboration with Siemens Corporate Research, Munich and the University of Stuttgart. It currently features a lexicon with about 2400 entries (full forms), and a grammar with approximately 1200 syntactic rules, of which about 350 constitute a subgrammar for temporal expressions. The system has been tested on several thousand word lattices from a corpus of spoken language appointment scheduling dialogues specifically collected for the project. On single sentence string input, 80–90% of the sentences are correctly analyzed. On actual full speaker-turn based lattice input taken directly from the speech recognition, the system performance decreases to some 60%. The semantic part processes about 90% of the turns the syntax can deal with.

The Japanese grammar has been developed together with DFKI, Saarbrücken and at the moment comprises a lexicon of approximately 400 words, complemented with a grammar of some 110 rules. Amongst others, zero anaphora, NPs without articles, embedded genitives, N-N compounds, propositional complements with control structure, classifiers, focus postpositions, PP-subjects, and discourse particles are covered (Mori, 1996). In terms of successful processing, the performance of the Japanese part actually is somewhat better than German one. This is mainly due to the fact that the Japanese domain used is very much more restricted.

4 A formalism for underspecificied representations

Since the Verbmobil domain is related to discourse rather than isolated sentences, we have chosen a variant of Kamp's Discourse Representation Theory, DRT (Kamp and Reyle, 1993) as the basis of our work. Thus, we adhere to a logical, model theoretic approach to semantics. To allow for underspecification of several linguistic phenomena we are interested in, however, we have chosen a formalism that is suited to represent underspecified structures: LUD, description Language for Underspecified Discourse representations (Bos *et al.*, 1996). Conceptually, the process of creating a LUD from natural language expression is the following:

- Assign a name (a *label*) to every basic formula of the object language (e.g., DRT).
- Allow variables ranging over labels (so-called *holes*) as the arguments of the predicates related to scope bearing expressions.
- Specify scopal constraints between labels and holes.

Although LUD is mainly aimed at mapping natural language utterances into DRSs, LUD is closely related to "Hole Semantics", which in (Bos, 1995) is shown to be suited for generation of underspecified representations of structures/formulæ of a wide range of logics (not just DRT). In fact, just like Hole Semantics, LUD is a meta-language.

Formally, a LUD-representation U is a triple $< H_U, L_U, C_U >$, where H_U is a set of holes (variables over labels), L_U is a set of labeled conditions, and C_U is a set of constraints. A *plugging* is a mapping from holes to labels. For each plugging there is a corresponding DRS. The syntax of labeled conditions is defined as:

1. If x is a discourse marker, then $dm(x)$ is a LUD-condition;
2. If P is a symbol for an n-place relation, $x_1, \ldots, x_n$ are discourse markers, then $pred(P, x_1, \ldots, x_n)$ is a LUD-condition;
3. If l is a label for a LUD-condition, then $\neg l$ is a LUD-condition;
4. If l_1 and l_2 are labels for LUD-conditions, then $l_1 \rightarrow l_2$, $l_1 \wedge l_2$ and $l_1 \vee l_2$ are LUD-conditions;
5. Nothing else is a LUD-condition.

There are two types of constraints in LUD-representations, *subordination* ($\leq$) and *presupposition* (α). Thus, we additionally have that if l_1, l_2 are labels, h is a hole, then $l_1 \leq h$ and $l_1 \alpha l_2$ are LUD-constraints.

Depicted graphically, the resulting representations look like the one in Figure 1, with the scopal subordination constraints encoded in the arrows (if a is outscoped by b, i.e. $a \leq b$, then there is an arrow pointing from a to b). In the example, we have got the situation where the semantic information with label l_2 is in the scope of the predicates for '*tabun*', '*ichioo*', and the (declarative) sentence mood. The modality adverbs are both in the scope of the mood ($l_1 \leq h_2$, $l_7 \leq h_2$), while the relation between the two adverbs is left underspecified.

5 Implementation

For building LUD-representations we use a lambda-operator and functional application in order to compositionally combine simple LUD-representations to complex ones. In

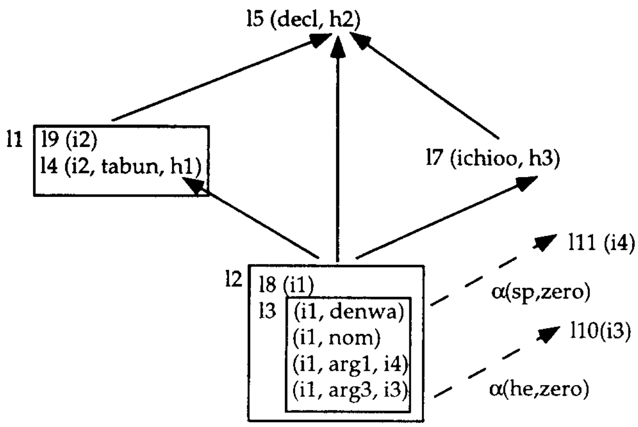

Figure 1: The LUD-representation for *Ichioo tabun denwa shi masu*

this section, this construction process will be explained by showing how the underspecification of the phenomena mentioned in Sections 1 and 2 actually has been implemented in the LUD-formalism within the Verbmobil system.

5.1 Construction of underspecified representations

In addition to underspecification, two other basic principles guide the semantic construction in Verbmobil: keep as much as possible of the semantic information lexicalized and pass the information up from the terminal nodes of a parse tree to the input nodes in a compositional manner.

Keeping most of the information in the lexicon (rather than in the grammar rules, as traditionally) reflects a strong trend both in unification-based grammar approaches in general as well as in most approaches to computational semantics. The overall idea is to keep the grammar rules as simple as possible — which in turn may result in rather complicated lexica. The result here is that a large part of the interesting work actually is done at the lexical level.

The principle of *compositionality* is quite central to the formalization of the semantic construction. Compositionality means that the interpretation of a phrase is a function of the interpretations of its subphrases. In the grammar rules, we then allow for information passing in three ways: trivial composition, function-argument application, and modifier-argument application.

The trivial composition manifests itself mainly in rules which are inherently (semantically) unary branching. That is, rules which either are syntactically unary branching, or where the semantics of at the most one of the daughter (left-hand side) nodes need to influence the interpretation of the mother (right-hand side) node.

The two types of application rules are in fact quite similar to each other and appear on all (semantically) binary branching rules of the grammar. (Of course, the TUG grammar formalism allows for rules which are not in normal form, i.e., which are more than binary branching. However, these are actually reduced to normal form on the semantic side by multi-application rules.)

In functor-argument application the main part of the semantic information is passed between the mother node and the functor (semantic head). In modifier-argument application the main part is passed up from the argument. The main difference between these two rule types pertains to the subcategorization schemes: In functor-argument application, the functor subcategorizes for the argument, the argument may optionally subcategorize for the functor, and the mother subcategorizes for whatever *is left* on the functor's subcategorization list after the argument having been removed from it.

In modifier-argument application, in contrast, the modifier must subcategorize for the argument (only), while the argument does not subcategorize for the modifier, so that the mother's subcategorization list is identical to that of the argument. In principle, we thus only need three different types of grammar rules:

```
lud_eq(Mother,Daughter) short_for
    subcat(Daughter,Subcat),
    subcat(Mother,Subcat),
    Mother:<all other features> = Daughter:<all other features> .

lud_fun_arg(Mother,Fun,Arg) short_for
    modifier(Arg,no),
    optional_subcat(Arg,Fun),
    subcat(Fun,[Arg|Subcat]),
    subcat(Mother,Subcat),
    Mother:<all other features> = Fun:<all other features> .

lud_mod_arg(Mother,Mod,Arg) short_for
    modifier(Mod,yes),
    subcat(Mod,[Arg]).
    subcat(Arg,Subcat),
    subcat(Mother,Subcat),
    Mother:<all other features> = Arg:<all other features> .
```

5.2 Underspecified representations for Japanese phenomena

To be more concrete, we will show what the underspecified representations look like in our formalism and explain the construction process. As an example of the interaction between the scopal relations of two modality adverbs, the LUD for "*Ichioo tabun denwa shi masu*" (*It is just possible that I will call you*), is the one already shown in Figure 1: it is thus left underspecified whether '*tabun*' has scope over '*ichioo*', or vice versa.

Looking at the noun phrase example of Section 2, "*Itsumo iroiro kaigi ga hait te ori masu*" (*Various conferences are scheduled in every time-slot*), the last four words form the verb phrase. '*hait*' is the main verb and '*ori*' an auxilliary, with '*te*' and '*masu*' being inflectional affixes. Since the main semantical information comes from the main verb, the affixes are treated as modifiers on the respective verb. The auxiliary is in turn treated as a modifier on '*hait*'. So, the lexical entry for e.g. '*masu*' mainly introduces a piece of information (namely the honourific form) which is passed up in the purely compositional part of the analysis tree. Thus the lexicon entry of '*masu*' abstractly is

```
modifier(yes),
honourific(DM,masu,HonorLabel)
subcat(masu,[Verb])
instance(Verb,DM)
```

where the label **HonorLabel** identifies the semantic object **honourific**. This is applied to **DM** which in due time will be bound to the discourse marker introduced by the verb (for which '*masu*' subcategorises). Thus the above entry introduces an honourific level on the main verb.

The main verb '*hait*' itself is intransitive. Thus it looks for one argument, namely its subject (**arg3**). The lexical entry is basically

```
subcat([Subject])
role(DM,arg3,Subject,VerbLabel)
hait(DM,VerbLabel)
dm(DM,DmLabel)
group(VerbLabel,DmLabel,GroupLabel)
leq(GroupLabel,TopHole)
```

where the first two lines state that an **arg3** is subcategorized for, while the third line gives the verb's own semantic object (identified by the label **VerbLabel**). Since a verb introduces a discourse marker, the label of the entire structure is the label **Label** which groups together the verb's label and the label **DmLabel** of the discourse marker. Finally, the **leq** constraint states that **Label** should be subordinate to a hole **TopHole**, which is the top-hole of the entire sentence.

Graphically, the verb phrase then looks as shown in the bottom part of Figure 2, where **DmLabel** thus is l_{10}, **VerbLabel** is l_5, **GroupLabel** l_2, and h_2 is the top-hole.

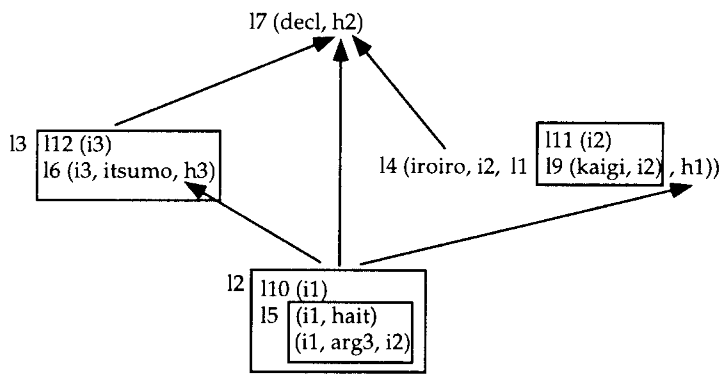

Figure 2: The LUD-representation for *Itsumo iroiro kaigi ga hait te ori masu*

The rest of the sentence is built up by identifying '*iroiro*' as quantifier which gets (functionally) applied to the noun '*kaigi*', forming an NP. The quantifier in fact subcategorizes for both its restriction (here, the noun) and its body (here, the verb). The lexical entry is thus

```
subcat([Restriction,Body])
quant(iroiro,RestrictionDM,RestrictionLabel,QuantHole,QuantLabel)
leq(BodyLabel,QuantHole)
leq(QuantLabel,TopHole)
```

We see that the quantification is over the discourse marker of the restriction and that the quantifier itself introduces a hole **QuantHole** for its underspecified scope. The only thing which is clear about the scope is that the quantifier should be subordinate to the top-hole of the sentence, while it indeed should take scope over its own body argument.

The postposition '*ga*' subcategorizes for the NP and thus helps in forming a PP acting as the subject by functional application. The VP again gets applied to the subject, forming a complete sentence:

```
s_pp_vp(S,Pp,Vp) short_for
    lud_fun_arg(S,Vp,Pp).
```

The **subcat** list of the VP thus in this case contains exactly one element, namely the subject-PP. On top of this S-structure, the adverb '*itsumo*' appears as a modifier:

```
s_advp_s(S,Advp,Sa) short_for
    lud_mod_or_fun_arg(S,Advp,Sa)
```

However, the rule states that either modificational or functional application may take place, depending on whether the adverb is lexically defined to be a modifier or not. In fact, the lexical entry is

```
modifier(yes)
modality(itsumo,DM,ModalHole,ModalLabel)
dm(DM,DmLabel)
group(ModalL,DmLabel,GroupLabel)
subcat([Argument])
leq(ArgumentLabel,ModalHole)
leq(GroupLabel,TopHole)
```

The first line shows that modifier-argument application is the appropriate choice. The semantic objects introduced by the adverb is a **modality** and a discourse marker. The labels of these two are grouped together under **GroupLabel**. Again, the argument is specified to be subordinate to the hole (the scope) of the adverb, while the adverb itself is subordinate to top-hole of the sentence. The LUD produced is thus

```
l12-dm(i3)                    l3-group([l6,l12])
l11-dm(i2)                    l2-group([l5,l10])
l10-dm(i1)                    l1-group([l9,l11])
l9-kaigi(i2)                  leq(l3,h2)
l5-hait(i1)                   leq(l2,h3)
l8-honourific(i1,masu)        leq(l2,h2)
l7-mood(decl,h2)              leq(l2,h1)
l6-modality(i3,itsumo,h3)     leq(l4,h2)
l5-role(i1,arg3,i2)           sh_plug(h3,l4)
l4-quant(iroiro,i2,l1,h1)     sh_plug(h2,l3)
                              sh_plug(h1,l2)
```

which corresponds to the graphics shown in Figure 2. As before, the fact that the objects labeled l_3 and l_4 appear at the same level in the picture illustrates the fact that there exists no subordination relation between the adverb and the quantifier.

In addition, the LUD also contains information about the most possible resolution of the ambiguity. *Resolution* is the term generally used for the process of going from an underspecified representation to an unambiguous one (similar to choosing one of the readings in (2)). Here the resolution is stated in the "plugging" obtained by the semantic heads of each partial structure, roughly following in the word-order. In this case, the **sh_plug** ("semantic-head based plugging") objects in the LUD state that the top-hole of the structure (h_2) most likely is plugged by the object labeled l_3. That is, that '*itsumo*' most likely outscopes '*iroiro*', given the word-order, as further described in (Gambäck and Bos, 1996).

6 Conclusions and future work

We have described a system for treating underspecified semantic representations, specifically aimed at some phenomena particular to Japanese. The system has been implemented as part of the Verbmobil spoken-language machine translation system, which also was briefly described. The representation language used, LUD, was outlined in Section 4, while the main part of the paper was devoted to describing how underspecified representations can be built up in LUD.

The system described is indeed quite small, but in a second four-year phase of the Verbmobil project (starting at the beginning of 1997), it will be extended to cover other domains. The lexicon size will be increased to some 10k words. Still, there remains plenty of work to be done on the resolution side of underspecification, as well as on the side of underspecification itself. In particular, Pinkal's "third level" of underspecification phenomena (see Section 2), i.e., underspecification of ambiguities caused by for example the syntactic structure, still needs to be addressed in more detail.

References

Hiyan Alshawi, ed., D. Carter, J. van Eijck, B .Gambäck, R.C. Moore, D.B. Moran, F.C.N. Pereira, S.G. Pulman, M. Rayner, and A.G. Smith. 1992. *The Core Language Engine.* The MIT Press, Cambridge, Massachusetts.

Hiyan Alshawi and Richard Crouch. 1992. Monotonic Semantic Interpretation. *Proc. 30th Annual Meeting of the Association for Computational Linguistics*, pp. 32–39, Newark, Delaware. ACL.

Hans Ulrich Block and Stefanie Schachtl. 1992. Trace and Unification Grammar. *Proc. 14th Int. Conf. on Computational Linguistics*, vol. 2, pp. 658–664, Nantes, France. ACL.

Johan Bos. 1995. Predicate Logic Unplugged. *Proc. 10th Amsterdam Colloquium*, vol. 1, pp. 133–142, Amsterdam, Holland.

Johan Bos, Björn Gambäck, Christian Lieske, Yoshiki Mori, Manfred Pinkal, and Karsten Worm. 1996. Compositional Semantics in Verbmobil. *Proc. 16th Int. Conf. on Computational Linguistics*, vol. 1, pp. 131–136, København, Denmark. ACL.

Robin Cooper, R. Crouch, J. van Eijck, C. Fox, J. van Genabith, J. Jaspars, H. Kamp, D. Milward, M. Pinkal, M. Poesio, S.G. Pulman. 1996. Using the Framework. FraCaS Deliverable D16, University of Edinburgh, Edinburgh, Scotland.

Björn Gambäck and Johan Bos. 1996. Semantic-Head Based Resolution of Scopal Ambiguities. Verbmobil technical report, Universität des Saarlandes, Saarbrücken, Germany. (forthcoming).

Megumi Kameyama. 1995. The Syntax and Semantics of the Japanese Language Engine. In R. Mazuka and N. Nagai, eds., *Japanese Sentence Processing*, pp. 153–176. Lawrence Erlbaum.

Hans Kamp and Uwe Reyle. 1993. *From Discourse to Logic: An Introduction to Modeltheoretic Semantics of Natural Language, Formal Logic and DRT.* Kluwer, Dordrecht, Holland.

Martin Kay, Jean Mark Gawron, and Peter Norvig. 1994. *Verbmobil: A Translation System for Face-to-Face Dialog.* Number 33 in Lecture Notes. CSLI, Stanford, California.

Yoshiki Mori. 1996. Multiple Discourse Relations on the Sentential Level in Japanese. *Proc. 16th Int. Conf. on Computational Linguistics*, vol. 2, pp. 788–793, København, Denmark. ACL.

Manfred Pinkal. 1995. Radical Underspecification. *Proc. 10th Amsterdam Colloquium*, vol. 3, pp. 587–606, Amsterdam, Holland.

Uwe Reyle. 1993. Dealing with Ambiguities by Underspecification: Construction, Representation and Deduction. *Journal of Semantics*, 10:123–179.

Wolfgang Wahlster. 1993. VERBMOBIL: Translation of Face-to-Face Dialogs. *Proc. 3rd Euro. Conf. on Speech Communication and Technology*, pp. 29–38, Berlin, Germany.