26

Information Structure and Minimal Recursion Semantics

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26.1 Introduction

Comparing English and Finnish, and simplifying a complex issue very much, we can say that English has fixed word order and Finnish has free word order. Syntactic theories such as HPSG (Sag and Wasow, 1999) have provided relatively successful descriptions of English, using a phrase structure approach to capture generalizations about fixed word order. Software tools such as LKB (Copestake, 2000) have been developed and made freely available to provide good support for implementing these descriptions.

Free word order in Finnish is described in depth by Vilkuna (1989), both in terms of syntax and its discourse functions. Theories such as HPSG have been much less successful in providing descriptions of languages such as Finnish, where discourse functions play a major role in word order. One of the problems in HPSG is that its account of information structure and discourse functions has not yet been sufficiently developed. This paper[1] addresses one aspect of this issue, namely what kind of representation is appropriate for information structure in HPSG. Another paper in this volume (Jokinen, 2005) presents an implementation of Finnish discourse syntax in an HPSG framework using LKB.

Sections 26.2 and 26.3 describe two different approaches to representing information structure: a syntax-oriented approach which has been proposed

[1] An earlier version of this paper (Wilcock, 2001) was presented at the 13th Nordic Conference on Computational Linguistics, Uppsala, 2001.

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in HPSG, and a semantics-oriented approach which has been used in a practical dialogue system. In both cases we note the problem of representing focus scope. Section 26.4 briefly compares the functional approach taken in Systemic Functional Grammar.

Section 26.5 describes the Minimal Recursion Semantics (MRS) representation developed for HPSG, and shows how quantifier scope is handled in MRS. Section 26.6 proposes a way to extend MRS to include information structure. We raise the question whether focus scope can be handled in MRS in a similar way to quantifier scope, and we show how a wide range of focus scope examples can be treated in the extended MRS representation.

26.2 Information Structure: A Syntactic Approach

A representation for information structure in HPSG was proposed by Engdahl and Vallduví (1996). Arguing that information structure is a distinct dimension, which should not be associated only with phonology, only with syntax, or only with semantics, they propose that a feature INFO-STRUCT should be located within the CONTEXT[2] feature in the HPSG framework, rather than in CATEGORY (syntax) or CONTENT (semantics). INFO-STRUCT includes FOCUS and GROUND, the latter including LINK and TAIL.

However, the specific representation which they use is syntactic: LINK and FOCUS are equated with the syntactic constituents (NPs and VPs) which realize the topic concept and the focus information. As the primary concern of Engdahl and Vallduví (1996) is with information *packaging*, this has the advantage of facilitating the description of the realization of information structure (by intonation in English, by word order in Catalan), but it has the major disadvantage that the packaging is only indirectly tied to the information which is packaged, which is itself part of the semantic content. In a footnote, Engdahl and Vallduví themselves suggest that it would be more appropriate for the value of INFO-STRUCT to be structure-shared with the CONTENT information.

26.2.1 Focus Scope in a Syntactic Approach

This syntax-based representation of information structure enables the distinction between narrow focus and wide focus to be represented. Engdahl and Vallduví give the example *The president hates the Delft china set* which can be interpreted either with narrow focus on the object noun phrase (26.1) or with wide focus on the whole verb phrase (26.2).

(26.1) The president hates [F the Delft china set].

(26.2) The president [F hates the Delft china set].

[2] There are a number of issues concerning the role of the CONTEXT feature in HPSG. Some of them are discussed by Wilcock (1999).

To represent these alternatives, the value of FOCUS at higher nodes (S and VP) is equated with the smaller syntactic constituent (the object NP) to represent the narrow focus reading, or with the larger syntactic constituent (the whole VP) to represent the wide focus reading, as shown by examples (17) and (18) of Engdahl and Vallduví (1996).

This would be an elegant way to capture the narrow and wide focus readings. However, there are a number of cases where informational partitioning does not correspond to syntactic constituency. Among the examples given by Engdahl & Vallduví are subject-verb focus (26.3) and complex focus (26.4):

(26.3) What happened to the china set? [F The BUTLER BROKE] the set.

(26.4) Who did your friends introduce to whom?
John introduced BILL to SUE, and **Mike** introduced ...

To handle these examples, Engdahl & Vallduví change the representation so that set values will be used: the value of FOCUS will not be a single syntactic constituent which exactly spans the focus scope, but an otherwise arbitrary set of syntactic constituents which together make up the relevant sequence of words. The representation thereby loses its initial elegance. With this change, Examples 26.1 and 26.2 will have a singleton set value for FOCUS, and set values will also be used for LINK and TAIL.

26.2.2 HPSG vs. CCG

Despite adopting a syntax-oriented representation, Engdahl and Vallduví (1996) argue that information structure is a distinct dimension, and locate INFO-STRUCT in the HPSG CONTEXT feature.

Steedman (1991) argues that there is a systematic correspondence between information structure, intonation and syntactic constituency, and it is a strength of Combinatory Categorial Grammar (CCG) that it allows suitable syntactic constituents which support this correspondence.[3] Engdahl and Vallduví (1996) argue that there is no such correspondence between information structure and syntactic constituency, and that it is a strength of HPSG's multidimensional representation that we are not forced to assume any such correspondence. Both approaches could be said to over-emphasise the role of syntax, in an area where semantics and pragmatics should be more central.

26.3 Information Structure: A Semantic Approach

We now examine a different approach to information structure, based on the practical requirements of dialogue modelling in robust dialogue system projects. These requirements appear to support a closer link between the information structure representation and the semantic representation. Dialogue

[3] Related problems in using HPSG for incremental generation, compared with CCG, are discussed by Wilcock (1998).

responses need to be generated from the semantic information. Old and new discourse referents need to be distinguished, and referents are usually identified by indices in the semantic representation. In addition, topic continuities and topic shifts need to be tracked, and the topics are also identified by semantic indices, even when a topic is some kind of event.

As an example of this approach we take the dialogue modelling framework used in PLUS (Pragmatics-based Language Understanding System), described by Jokinen (1994). In PLUS, the semantic representation consists of flat quasi-logical forms with simple indices for discourse referents. The dialogue manager component takes account of information structure and decides what semantic representations to supply to the generator. Jokinen defines **Topic** as a distinguished discourse entity which is talked about, and which is an instantiated World Model concept. **NewInfo** is a concept or property value which is *new* with respect to some Topic. The representation for both is based directly on the semantic representation. Jokinen gives an example from PLUS (Topics are in italics, NewInfo bold-faced):

(26.5) User: *I need a car*.
System: Do you want to **buy or rent** *one*?
User: **Rent**. (topic: *car*)
System: **Where**? (topic: *rent*)
User: In **Bolton**. (topic: *rent*)
...

Jokinen (1994) explains that in the first system contribution in (26.5), NewInfo is the disjunction 'buy or rent', which has the representation:

(26.6) Goal: know(s,[wantEvent(w,u,d),disj(d,b,r),
buyEvent(b,u,c,_),hireEvent(r,u,c,_),car(c),user(u)])
NewInfo: disj(d,b,r)

Compared with the syntax-oriented representation of information structure, this semantics-oriented representation appears to have the advantage of facilitating topic tracking and distinguishing old and new referents, due to the direct use of semantic indices (c = *car*, r = *rent*, etc.). Further examples of its use in practical dialogue modelling are described by Jokinen (1994). In the PLUS system, a pragmatics-based Dialogue Manager explicitly manages information structure. Response planning in the Dialogue Manager always starts from NewInfo, adding other content (such as Central Concept linking) only when necessary. This gives rise to natural, elliptical surface generation. This approach to generation from NewInfo has been developed further by Jokinen et al. (1998) and Jokinen and Wilcock (2003).

26.3.1 Focus Scope in a Semantic Approach

Central Concept (topic) and NewInfo (focus) are represented using QLFs with explicit indices for discourse referents. This facilitates distinguishing old and new information, but the QLF lacks explicit representation of scope. It would be useful to be able to represent focus scope ("narrow focus" and "wide focus"), and also to be able to represent quantifier scope. This issue will be addressed in Section 26.6.

Example 26.6 shows an interesting "disjunctive focus", where the disjunction itself is reified and has its own semantic index. Although many examples of narrow and wide focus can be elegantly represented in the PLUS approach, simply by NewInfo taking the appropriate index value, other examples cannot be represented by a single semantic index: if *hates* has semantic index h, the wide VP focus reading in (26.2) would need NewInfo to be both h and s. It is not possible to unify these indices, because the hating event (h) and the china set (s) are ontologically distinct items. The conclusion is that the value of NewInfo should be a *set* of indices, giving representations like those sketched in (26.7) (narrow NP focus) and (26.8) (wide VP focus):

(26.7) Semantics: hateEvent(h,p,s),president(p),Delft(s),china(s),set(s)
NewInfo: {s}

(26.8) Semantics: hateEvent(h,p,s),president(p),Delft(s),china(s),set(s)
NewInfo: {h,s}

This need for set-valued features, using sets of semantic indices to represent focus scope, is analogous to the need for set-valued features, using sets of syntactic categories, in the approach of Section 26.2.

26.4 Information Structure: A Functional Approach

In Sections 26.2 and 26.3 we described a syntax-oriented approach and a semantics-oriented approach, but our aim is to move towards a discourse-oriented approach to information structure, in which its representation should not be too closely tied to either syntax or semantics. This has long been a fundamental assumption in functionally-oriented frameworks.

For example, Teich (1998) illustrates how focus scope is handled in Systemic Functional Grammar. In the *function structures* in (26.9) and (26.10) there is a syntax-oriented layer (Subject-Finite-Object), a semantics-oriented layer (Actor-Process-Goal), and **two** further layers of discourse-oriented information.

(26.9)

Actor	Process	Goal
Theme	Rheme	
Given	New	
Subject	Finite	Object
Fred	*ate the beans*	

(26.10)

Actor	Process	Goal
Theme	Rheme	
Given		New
Subject	Finite	Object
Fred ate		*the beans*

26.5 Minimal Recursion Semantics

The kind of flat quasi-logical form (QLF) used in PLUS has the disadvantage that it lacks an adequate treatment of quantifier scope. Minimal Recursion Semantics (MRS), developed by Copestake et al. (1997) in the HPSG framework, is a flat indexed quasi-logical form like the one used in PLUS, but MRS provides a solution to the treatment of quantifier scope.

Both MRS and the indexed QLF of PLUS were motivated by the needs of machine translation, where "flat" representations are preferred over strongly head-driven representations, as the head in one language may not correspond to the head in another language. Like the QLF, MRS depends on the use of indices to represent dependencies between the terms in the flat list. Before the development of MRS, HPSG used indices only for entities of type *nominal_object*, to assign them to semantic roles as participants in *states of affairs* and to carry agreement features. In MRS, indices are also used for events, as in the QLF.

One difference between MRS and the QLF is that MRS uses typed feature structures instead of ordinary logical terms. Each element in the list of semantic terms is an HPSG typed feature structure of type *relation*. This facilitates the integration of MRS into HPSG.

26.5.1 Quantifier Scope in MRS

Another difference, which makes MRS a significant improvement over the QLF, is that MRS supports the representation of quantifier scope, either fully resolved or underspecified. This is done by including *handles* which label each term in the list. (As a musical joke about semantic *composition*, the handle feature is named HANDEL and the list feature is named LISZT by Copestake et al. (1997)).

Scope can be represented by means of the handles, while maintaining the flat list representation, without the nesting required when operators are used to represent scope. The handles are unified with the role arguments of other

relations. This technique not only enables recursive embedding to be simulated, but also allows quantifier scope to be either fully resolved or underspecified. We give an example from Copestake et al. (1997) using their linear notation to save space. The unscoped representation of *every dog chased some cat* is:

(26.11) 1:every(*x*,3,*n*), 3:dog(*x*), 7:cat(*y*), 5:some(*y*,7,*m*), 4:chase(*e*,*x*,*y*)
top handle: *p*

Here 1, 3, 4, 5, 7 are handles and *m*, *n* and *p* are variables over handles. This unscoped representation can be further instantiated to give scoped representations by unifying *m*, *n* and *p* with the appropriate handles:

(26.12) 1:every(*x*,3,4), 3:dog(*x*), 7:cat(*y*), 5:some(*y*,7,1), 4:chase(*e*,*x*,*y*)
top handle: 5 (wide scope *some*)

(26.13) 1:every(*x*,3,5), 3:dog(*x*), 7:cat(*y*), 5:some(*y*,7,4), 4:chase(*e*,*x*,*y*)
top handle: 1 (wide scope *every*)

The top handle allows the clause to be embedded in a longer sentence. In the scoped representations, it is unified with the widest scoped quantifier.

26.6 Information Structure and MRS

If information structure is a distinct dimension, as argued by Engdahl and Vallduví (1996), its representation should not be too closely tied to either syntax or semantics. However, we noted that the semantics-oriented approach had advantages in topic-tracking and distinguishing old and new referents due to its direct use of semantic indices. A representation for use in practical dialogue systems, while not directly tied to either syntax or semantics, should nevertheless be relatively close to the semantic information. We therefore take the MRS representation as a starting point for a representation of information structure in HPSG, but follow Engdahl and Vallduví (1996) in locating INFO-STRUCT in CONTEXT.

To avoid confusion, we also follow Engdahl & Vallduvi's feature terminology: INFO-STRUCT includes FOCUS and GROUND, and GROUND includes LINK and TAIL. However, the values of FOCUS, LINK and TAIL will not be syntactic constituents, they will be variables over handles. These variables will be unified with particular handles in the semantics in order to represent specific focus scopings and topic interpretations. An advantage of handles is that they can be unified with each other without implying that semantic entities lose their distinct identities. This raises the unresolved question whether focus scope can be handled in MRS in a similar way to quantifier scope. However, we will follow the earlier approaches and use set values. In our representation, these will be sets of handles.

We start by adding information structure to the MRS quantifier example of

Copestake et al. (1997), *every dog chased some cat*. If we assume a context (perhaps *what did every dog chase?*) in which *every dog* is interpreted as link, and *some cat* has narrow focus, we can use a representation such as:

(26.14) 1:every(*x*,3,4), 3:dog(*x*), 7:cat(*y*), 5:some(*y*,7,1), 4:chase(*e*,*x*,*y*)
TOP-HANDLE:5, LINK:{1}, TAIL:{4}, FOCUS:{5}

By contrast, if we assume a context (perhaps *what did every dog do?*) in which there is wide focus across *chased some cat*, we need to include handles 4 and 5 in the value of FOCUS, giving:

(26.15) 1:every(*x*,3,5), 3:dog(*x*), 7:cat(*y*), 5:some(*y*,7,4), 4:chase(*e*,*x*,*y*)
TOP-HANDLE:1, LINK:{1}, FOCUS:{4,5}

26.6.1 Focus Scope in MRS

We now sketch new MRS-based representations of some of the examples of Engdahl and Vallduví (1996). The alternative focus scope readings of examples (26.1) and (26.2) can be represented by (26.16) and (26.17):

(26.16) 1:the(*x*,2), 2:president(*x*), 3:the(*y*,4), 4:china(*y*), 4:set(*y*),
5:hate(*e*,*x*,*y*)
TOP-HANDLE:5, LINK:{1}, TAIL:{5}, FOCUS:{3} (narrow focus)

(26.17) 1:the(*x*,2), 2:president(*x*), 3:the(*y*,4), 4:china(*y*), 4:set(*y*),
5:hate(*e*,*x*,*y*)
TOP-HANDLE:5, LINK:{1}, FOCUS:{3,5} (wide focus)

Example (21) of Engdahl and Vallduví (1996), *The president* [F HATES] *the Delft china set*, is straightforward:

(26.18) 1:the(*x*,2), 2:president(*x*), 3:the(*y*,4), 4:china(*y*), 4:set(*y*),
5:hate(*e*,*x*,*y*)
TOP-HANDLE:5, LINK:{1}, TAIL:{3}, FOCUS:{5}

The more problematic subject-verb focus in example (26.3), [F *The* BUTLER BROKE] *the set*, can be represented in MRS by:

(26.19) 1:the(*x*,2), 2:butler(*x*), 3:the(*y*,4), 4:set(*y*), 5:break(*e*,*x*,*y*)
TOP-HANDLE:5, TAIL:{3}, FOCUS:{1,5}

The complex focus in example (26.4) can be represented in MRS as shown in (26.20), using the NAME relation of Copestake et al. (1997).

(26.20) 1:NAME(*x*,John), 2:NAME(*y*,Bill), 3:NAME(*z*,Sue),
5:introduce(*e*,*x*,*y*,*z*)
TOP-HANDLE:5, LINK:{1}, TAIL:{5}, FOCUS:{2,3}

Finally example 26.21 shows one possible MRS-based representation for the PLUS disjunctive focus example in (26.5), *Do you want to* **buy or rent** *one?*.

(26.21) 1:want(*w*,*u*,2) 2:or(3,4) 3:buy(*b*,*u*,*c*) 4:rent(*r*,*u*,*c*) 5:car(*c*), 6:user(*u*)
TOP-HANDLE:1, LINK:{1}, TAIL:{5}, FOCUS:{2}

26.7 Conclusion

We have compared two different approaches to representing information structure: a syntax-oriented approach proposed in HPSG, and a semantics-oriented approach used in a practical dialogue system. In both cases we noted that the problem of representing focus scope requires the use of set-valued features.

We noted that the Minimal Recursion Semantics (MRS) representation used for HPSG can represent quantifier scope using handles. We proposed in Section 26.6 a way to extend MRS to include information structure. This raises the unresolved question whether focus scope can be handled in MRS in a similar way to quantifier scope. Using a simpler, set-valued approach we showed how narrow focus, wide focus, subject-verb focus, complex focus and disjunctive focus can be treated in this extended MRS representation.

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