DOI:
10.1007/978-1-4020-5958-2_6

Citation for published version (APA):
Fernández, R., Ginzburg, J., Gregory, H., & Lappin, S. (2001). Shards: Fragment Resolution In Dialogue. In *Computing Meaning* (pp. 156-172). (Studies in Linguistics and Philosophy; Vol. 83). Springer Netherlands. https://doi.org/10.1007/978-1-4020-5958-2_6

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SHARDS: FRAGMENT RESOLUTION IN DIALOGUE

1. Introduction

A major challenge for any grammar-driven text understanding system is the resolution of fragments. Basic examples include **bare NP answers** (1a), where the bare NP *John* is resolved as the assertion *John saw Mary*, and **sluicing** (1b), where the *wh*-phrase *who* is interpreted as the question *Which student saw John*.

(1) a. A: Who saw Mary?
B: John

b. A: A student saw John.
B: Who?

Either the antecedent or the fragment (or both) may be embedded:

(2) a. A: Bill wonders who saw Mary.
B: John. (*John saw Mary*)

b. A: Bill thinks a student saw John.
B: Who? (*Which student does Bill think saw John?*)

c. A: Who saw Mary?
B: John thinks Bill. (*John thinks Bill saw Mary*)

d. A: A student saw John.
B: Bill wonders who. (*Bill wonders which student saw John*)

2. Theoretical Background

2.1. *Ellipsis Resolution: A Theory of Context and Parallelism*

The task of accounting for many ellipsis phenomena can be viewed as involving: (a) locating an element in the context (the **source**) parallel to the ellipsis element (the **target**); and (b) computing from contextual information a property which, applied to the target, yields the resolved content. This view underlies work on Higher Order Unification (HOU) (Dalrymple et al., 1991; Pulman, 1997), and also the Dynamic Syntax approach of (Kempson et al., 1999). We adopt a similar approach in this paper. We extend our account to adjuncts, and we briefly consider an alternative approach to adjunct fragments. We also provide an explicit account of the relation between this parallelism and dialogue context (see Section 5 below).

We adapt the situation semantics-based theory of dialogue context developed in the KOS framework (Ginzburg, 1996; Ginzburg, 1999; Cooper et al., 1999). This combines a structuring of the propositional common ground of conversation (Webber, 1991; Asher, 1993) with a modelling of discourse topic based on (Carlson, 1983). In (Ginzburg and Sag, 2001) this framework is integrated into recent work in Head Driven Phrase Structure Grammar (HPSG) (Pollard and Sag, 1994; Sag, 1997). Following (Ginzburg and Sag, 2001) we define two new attributes within the CONTEXT (CTXT) feature structure: Maximal Question Under Discussion (MAX-QUD), whose value is of sort *question*, and Salient Utterance (SAL-UTT), whose value is a set of elements of type *sign*.

In this framework, questions are represented as semantic objects comprising a set of parameters – that is, restricted indices – and a proposition PROP as in (3). This is the feature structure counterpart of the λ-abstract $\lambda\pi(\ldots\pi\ldots)$. In a *wh*-question the PARAMS set represents the abstracted INDEX values associated with the *wh*-phrase(s). For a polar question the PARAMS set is empty.

(3) $$\begin{bmatrix} \textit{question} & \\ \text{PARAMS} & \{\pi, ...\} \\ \text{PROP} & \begin{bmatrix} \textit{proposition} & \\ \text{SIT} & \\ \text{SOA} & \begin{bmatrix} \textit{soa}(\ldots\pi\ldots) \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

In general a number of such questions may be available in a given discourse context, of which one is selected as the value of MAX-QUD. An algorithm is given below for the simple cases discussed in the present system, but it will be apparent that the system is flexible enough to allow for extension to more complicated dialogues.

The feature SAL-UTT represents a distinguished constituent of the utterance whose content is the current value of MAX-QUD. In information structure terms, SAL-UTT can be thought of as a means of underspecifying the subsequent focal (sub)utterance or as a potential *parallel element*. MAX-QUD corresponds to the ground of the dialogue at a given point.[1] Since SAL-UTT is a *sign*, it enables us to encode syntactic *categorial* parallelism, including case assignment for the fragment.[2]

SAL-UTT is computed as the (sub)utterance associated with the role bearing widest scope within MAX-QUD:

– For *wh*-questions, SAL-UTT is the *wh*-phrase associated with the PARAMS set of the question.[3]
– If MAX-QUD is a question with an *empty* PARAMS set, the context will be underspecified for SAL-UTT. Its possible values are either the empty set or the utterance associated with the widest scoping quantifier in MAX-QUD. This will be invoked to resolve sluicing.[4]

Our grammar also includes the non-local feature C(ONTEXTUAL)-PARAM(ETER)S, introduced by (Ginzburg and Cooper, 2004). This feature encodes the entire inventory of contextual parameters of an utter-

[1] For related notions concerning information structure see (Vallduví, 1992; Krifka, 1992; Rooth, 1993; Grosz et al., 1995). In contrast to these works, the notions we utilise here are applied directly within a computational theory of dialogue.

[2] We invoke syntactic parallelism only for *matching conditions* between an elliptical form and a prior utterance. Thus, our approach is compatible with psycholinguistic work demonstrating the rapid decay of purely structural information (Fletcher, 1994). Indeed, by relating MAX-QUD and SAL-UTT in the way we do, our approach enables us to make strong predictions about the range of possible relations of categorial parallelism.

[3] More generally, the utterance associated with the PARAMS set when this is non-empty. An empty PARAMS set can arise when the antecedent is not an interrogative clause, for example in reprise or echo questions (mentioned in Section 6; see Ginzburg and Sag, 2001 for detailed discussion). In such cases, SAL-UTT will be the utterance of the constituent to be clarified.

[4] SAL-UTT can also be a set containing more than one member in contexts where MAX-QUD is a multiple question, as in (i) below. We leave the analysis of such phenomena to future research.

(i) A: Who arrived when?
B: Jo at 5, Mustafa at 7.

ance (proper names, indexicals and so on).[5] The values of C-PARAMS get amalgamated via lexical heads and are propagated in the same way as other non-local features, such as SLASH and WH. The set of parameters is inherited from head daughter to mother within headed structures by a Generalised Head Feature Principle (see Ginzburg and Sag, 2001).

2.2. *A Grammatical Framework for Fragments*

We adopt a version of HPSG, following (Sag, 1997; Ginzburg and Sag, 2001), which encodes information about phrases by cross-classifying them in a multi-dimensional type hierarchy. Phrases are classified not only in terms of their phrase structure schema or X-bar type, but also with respect to the informational dimension of CLAUSALITY. Clauses are divided into *inter alia* declarative clauses (*decl-cl*), which denote propositions, and interrogative clauses (*inter-cl*) denoting questions. Each maximal phrasal type inherits feature values from both these dimensions. This classification allows us to specify systematic correlations between clausal construction types and semantic content types .

In line with much recent work in HPSG and Categorial Grammar, we do not treat ellipsis by positing a phonologically null head. Rather, we assign fragments to a subtype of the phrasal type *head-only-phrase*. [6] We first deal with fragments that constitute arguments, and then turn to adjuncts in Section 4. Bare argument phrases are analysed by means of the phrasal type *headed-fragment-phrase* (*hd-frag-ph*). The top-most constraint associated with this type is shown in (4).

This constraint has two significant effects. First, it ensures that the category of the head daughter (the fragment) is identical to that specified by the contextually provided SAL-UTT. Second, the constraint coindexes the head daughter with the SAL-UTT. This will have the effect of ‘unifying in’ the content of the former into a contextually provided content. Thus, the (sub)utterance in the antecedent picked up by SAL-UTT links the bare phrase to the appropriate argument-role, and enforces categorial identity.

[5] The presence of this feature allows signs to play a role similar to the role traditionally associated with ‘meanings’, i.e. to function as abstracts with roles that need to be instantiated. See (Ginzburg and Cooper, 2004) for more discussion.

[6] In former versions of the system (see Ginzburg et al., 2001), fragments were analysed as non-headed bare phrases, the fragment being the non-head daughter.

(4) *hd-frag-ph*:

$$\left[\begin{array}{ll} \text{HEAD} & \left[\begin{array}{l} v \\ \text{VFORM } \textit{fin} \end{array}\right] \\ \text{CTXT}|\text{SAL-UTT} & \left\{\left[\begin{array}{l} \text{CAT } \boxed{1} \\ \text{CONT}|\text{INDEX } \boxed{2} \end{array}\right]\right\} \\ \text{HD-DTR} & \left[\begin{array}{l} \text{CAT } \boxed{1} \\ \text{CONT}|\text{INDEX } \boxed{2} \end{array}\right] \end{array}\right]$$

We define two types by means of which we analyse argument fragments. Both are subtypes of *hd-frag-ph*: *declarative-fragment-clause* (*decl-frag-cl*) for "short answers" and *sluice-interrogative-clause* (*slu-int-cl*) for sluices. These subtypes are also subtypes of *decl-cl* and *inter-cl*, respectively. As a result, their content is in the first case a proposition and in the second a question.

We start by considering *decl-frag-cl*. The only information, beyond that inherited from *hd-frag-ph* and *decl-cl*, which remains to be specified concerns the scoping of quantifiers and the semantic content. Whereas in most headed clauses the content is entirely (or primarily) derived from the head daughter, here it is constructed for the most part from the contextually salient question (MAX-QUD). This provides the values for the situation and nucleus features of the phrase's CONTENT. With respect to quantifier scoping, we assume the following:

– **Quantifier scoping**. If the bare phrase is (or contains) a quantifier Q, then Q is scoped in wider than the existing quantifiers, if any, in the contextually salient question (MAX-QUD).[7]

The constraint particular to *decl-frag-cl* is, hence, as represented in (5). This constraint identifies the SIT and NUCLEUS values of the phrase's CONTENT with those of the MAX-QUD. It also ensures that if the head daughter contributes a parameter to the store, due to the presence of a *wh*-phrase, that parameter remains stored, i.e. is included in the mother's STORE value.

Turning to sluices (*slu-int-cl*), most existing linguistic work on sluicing has assumed (on the basis of embedded uses in monologue) that

[7] For motivation for this view see (Ginzburg, 1999; Ginzburg and Sag, 2001). In the latter work apparent exceptions to this are analysed on the basis of Skolem function interpretation of *wh*-phrases.

ONLY existentially quantified propositions can serve as antecedents (see e.g. Chung et al., 1995; Reinhardt, 1997). However the examples in (6), taken from (Ginzburg and Sag, 2001), show that the context for sluicing crucially involves the QUD-maximality of a question of the form *whether p*, where *p* is quantified and its widest-scoping quantifier is non-negative.[8]

(5) *decl-frag-cl*:

$$\left[\begin{array}{ll}
\text{HEAD} & \left[\text{IC} \;\; +\right] \\
\text{CONT} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{proposition}} \\ \text{SIT} & \boxed{2} \\ \text{SOA} & \left[\begin{array}{ll} \text{QUANTS} & \texttt{order}(\boxed{\Sigma_3}) \oplus \boxed{A} \\ \text{NUCL} & \boxed{5} \end{array}\right] \end{array}\right] \\
\text{STORE} & \boxed{\Sigma_1} \\
\text{MAX-QUD} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{question}} \\ \text{PARAMS} & \textit{non-empty-set} \\ \text{PROP} & \left[\begin{array}{ll} \multicolumn{2}{l}{\textit{proposition}} \\ \text{SIT} & \boxed{2} \\ \text{SOA} & \left[\begin{array}{ll} \text{QUANTS} & \boxed{A} \\ \text{NUCL} & \boxed{5} \end{array}\right] \end{array}\right] \end{array}\right] \\
\text{HD-DTR} & \left[\text{STORE} \;\; \boxed{\Sigma_3} \cup \boxed{\Sigma_1} \textit{set(param)}\right]
\end{array}\right]$$

(6) a. A: Many dissidents have been released.
B: Do you know who?

[8] (Singular) definites are an exception to this, allowing as they do only reprise/echo sluices:

(i) A: The murderer was obviously a vicious guy.
B: #who?/WHO?/#You don't know who?/

(ii) # which murderer was obviously a vicious guy?

Our account will associate the non-reprise sluice (i) with a content essentially synonymous with the non-elliptical (ii), which is indeed infelicitous in this context (i.e. as a non-reprise sluice).

b. A: Did anyone show up for class today?
B: Yes.
A: Who?

c. A: Can anyone solve the problem?
B: Gee, I wish I knew who.

d. A: No student supported the proposal.
B: hmm, # I wonder who (cf. I wonder who did.)

As with *decl-frag-cl*, the type *slu-int-cl* inherits a significant part of its specification through being a subtype of *hd-frag-ph* and *inter-cl*. The conditions that are specific to *slu-int-cl* pertain to content, which like *decl-frag-cl* is partially determined by the context, and quantifiers. We assume that:

– **Quantifier replacement**. The widest scoping quantifier Q in MAX-QUD's QUANTS list is removed from the QUANTS list of the content of a *slu-int-cl*. Thus, the widest scoping quantifier, if any, in the open proposition of the question after resolution will be whichever quantifier, if any, was previously scoped just narrower than Q.[9]

The constraint particular to *slu-int-cl* is shown in (8). The *wh*-phrase contributes a parameter to the STORE value of the head daughter, which is constrained to be a *non-empty set of parameters*. The parameter is then retrieved by identifying the head daughter's STORE value with the clause's PARAMS set.

This analysis can be extended to account for reprise sluices (7a) and elliptical literal reprises (7b).

(7) a. A: Mary sang.
B: WHO?

[9] (Lappin, 2005) points out that there are exceptions to this condition, as in (i).

(i) A: Each student will consult a supervisor.
B: Which one?

The most natural interpretation of B's utterance in (i) is *Which supervisor will each student consult?*. This reading takes the narrower scoped quantified NP 'a supervisor' as the SAL-UTT. We will be refining the scope conditions associated with *decl-frag-cl* and *slu-int-cl*, and the procedure for identifying the SAL-UTT in future work. (Ginzburg and Sag, 2001) discuss cases of this kind in terms of an analysis that uses Skolem functions.

b. A: Did Jo kowtow?
B: JO?

(8) *slu-int-cl*:

$$
\left[\begin{array}{ll}
\text{CONT} & \left[\begin{array}{ll} \textit{question} & \\ \text{PARAMS} & \boxed{\Sigma_1} \\ \text{PROP} & \left[\begin{array}{ll} \textit{proposition} & \\ \text{SIT} & \boxed{1} \\ \text{SOA} & \left[\begin{array}{ll} \text{QUANTS} & \boxed{A} \\ \text{NUCL} & \boxed{3}\end{array}\right]\end{array}\right]\end{array}\right] \\
\text{STORE} & \{\} \\
\text{CTXT} & \left[\begin{array}{ll}\text{MAX-QUD} & \left[\begin{array}{ll} \textit{question} & \\ \text{PARAMS} & \{\} \\ \text{PROP} & \left[\begin{array}{ll} \textit{proposition} & \\ \text{SIT} & \boxed{1} \\ \text{SOA} & \left[\begin{array}{ll} \text{QUANTS} & \left\langle \textit{n-neg-qf-rel}\right\rangle \oplus \boxed{A} \\ \text{NUCL} & \boxed{3}\end{array}\right]\end{array}\right]\end{array}\right]\end{array}\right] \\
\text{HD-DTR} & \left[\text{STORE} \quad \boxed{\Sigma_1}\textit{non-empty-set(param)}\right]
\end{array}\right]
$$

The resolution of reprise sluices such as B's utterance in (7a) is achieved by allowing a conversational participant to coerce a clarification question onto MAX-QUD.[10] The reprise sluice is then analysed as a *direct-insitu-interrogative-clause* (*dir-is-int-cl*), a phrasal type introduced by (Ginzburg and Sag, 2001) to analyse direct in-situ constructions like 'You gave the book to who?' and intonation questions such as 'You're hungry?'. The head daughter of a construction like (7a) is a *decl-frag-cl* in which the parameter which constitutes the content of the *wh*-phrase WHO remains in storage. The retrieval of this parameter is effected by the type *dir-is-int-cl*, which allows a question to be constructed by retrieving from storage zero or more parameters from a proposition-denoting head daughter. This is achieved by identifying the PROP value of the mother with the CONTENT value of the head daughter. The parameter introduced by the *wh*-phrase is included in the clause's PARAMS set.

[10] For a detailed account of these coercion mechanisms see (Ginzburg and Cooper, 2004).

Elliptical literal reprises like (7b) are also analysed by means of *dir-is-int-cl*. Again, a clarification question is coerced onto MAX-QUD, which allows us to analyse the fragment using the type *decl-frag-cl* as a head daughter of *dir-is-int-cl*. The crucial difference is that in (7b) there is no parameter to retrieve from storage, leading to a question with an empty params set, in other words a polar question ('Are you asking if JO kowtows?').

3. An Implemented System for Short Answers and Bare Sluiced Questions

Our fragment interpretation system consists of four main components:

I. An HPSG grammar. This is a substantially modified version of the grammar employed by (Lappin and Gregory, 1997; Gregory and Lappin, 1999; Ginzburg et al., 2001), extended as described in (Fernández, 2002) to cover a important part of the wide coverage grammar proposed in (Ginzburg and Sag, 2001). The grammar uses the types and features specified in Section 2 and is encoded in (Erbach, 1995)'s ProFIT system.

II. A dialogue record. When a clause has been parsed (and any ellipsis resolved as described below), its atribute value matrix (AVM) is first converted into a transitive network of Mother-Daughter-Relations (MDR list) and then stored in a dialogue record paired with an index (counter).[11] A list of MAX-QUD candidates is computed from the value CONT feature of each subclause and stored as a further component of the discourse record (the QUD-list or **candidate list**).

III. A CONTEXT resolution procedure. This assigns values from the dialogue record to the MAX-QUD and SAL-UTT features of the current clause C, according to the procedures specified in Section 2. The most recent element of the QUD-list which is compatible with the type constraints imposed by the bare argument phrase is selected as the value of MAX-QUD.[12] On the basis of the conditions

[11] In the simple dialogue sequences implemented so far, this indexing corresponds to a linear sequence of utterances, but the format can be enriched to capture more complicated dialogue structures.

[12] (Lappin, 2005) motivates the need for a more refined procedure to select the antecedent of a fragment phrase. He presents cases in which recency is

indicated in Section 2.1, the SAL-UTT is obtained from the sign whose content provides MAX-QUD.

IV. A bare clause resolution procedure. This computes the CONT of C as already described. The nucleus N is identified with that of the MAX-QUD, and the INDEX of the head daughter identified with that of the SAL-UTT, with the specified operations on the PARAMS set and on the QUANTS list. If the head daughter is an argument, its CAT is identified with that of SAL-UTT, enabling it to be assigned case.

The system as described produces AVMs for bare answers and reprise and non-reprise sluices corresponding to the structures argued for in the previous section.

An instructive case is the dialogue sequence in (9), where "cascaded" bare answers and sluices interact to give the specified interpretation of the final fragment *Mary*.

(9) A: Who saw John?
B: A girl. (= *A girl saw John.*)
A: Who? (= *Which girl saw John?*)
B: Mary. (= *A girl called Mary saw John*)

The simplified AVM for this final bare answer (various contextual restrictions on indices are suppressed) is shown in (11). Note that the procedure for assigning the CAT value to the fragment rules out cases of category mismatch such as those in (10):[13]

(10) a. A: Who saw Mo?
B: #to Jo.

b. A: Whose book did you read?
B: His/#He/#Him

Similarly the coindexation of the SAL-UTT and the head daughter in the CONT of the bare clause, identifies cases of semantic mismatch between the source and target.

overridden and more distant antecedents are preferred to type compatible candidates.

[13] This paper focuses on English. The existence of syntactic parallelism across utterances is far easier to demonstrate in case rich languages such as German, Russian, or Greek. For such data see e.g. (Ginzburg, 1999; Ginzburg and Sag, 2001).

(11)
$$\begin{bmatrix} \text{PHON} & \text{mary} \\ \text{CAT} & \text{S}[\mathit{fin}] \\ \text{C-PARAMS} & \left\{ \boxed{6}, \boxed{7} \begin{bmatrix} \text{INDEX} & \boxed{1} \\ \text{REST} & \left\{ \mathit{girl}(\boxed{1}), \mathit{person}(\boxed{1}) \right\} \end{bmatrix} \right\} \\ \text{CONT} \mid \text{PROP} \mid \text{SOA} & \boxed{3} \\ \text{CTXT} & \begin{bmatrix} \text{MAX-QUD} & \begin{bmatrix} \mathit{question} \\ \text{PARAMS} & \left\{ \boxed{7} \right\} \\ \text{PROP} & \begin{bmatrix} \text{SOA} & \boxed{3} \begin{bmatrix} \mathit{see\text{-}rel} \\ \text{SEE-ER} & \boxed{1} \\ \text{SEE EE} & \boxed{2} \end{bmatrix} \end{bmatrix} \end{bmatrix} \\ \text{SAL-UTT} & \begin{bmatrix} \text{CAT} & \boxed{5}\ \text{NP}[\mathit{nom}] \\ \text{INDEX} & \boxed{1} \end{bmatrix} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{PHON} & \text{mary} \\ \text{CAT} & \boxed{5} \\ \text{CONT} & \boxed{6} \begin{bmatrix} \text{INDEX} & \boxed{1} \\ \text{REST} & \left\{ \mathit{named}(\mathit{mary}(\boxed{1})) \right\} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

4. Adjunct Sluices

Until now we have dealt with cases of bare answers and sluices corresponding to *arguments*. Our system also covers *adjunct* sluices. We assume the following general account of the semantics of adjuncts. An adjunct has a CONT of type *soa*, i.e. a relation (*adjunct-relation*) with a parameter corresponding to a property of a SOA, and a ROLE whose value is identified with the SOA of the modified head.

(12)
$$\begin{bmatrix} \text{CONT} & \begin{bmatrix} \mathit{adj\text{-}rel} \\ \text{PARAM} & \mathit{param} \\ \text{SOA-ROLE} & \mathit{soa} \end{bmatrix} \end{bmatrix}$$

On this account, interrogative adjuncts are interpreted as abstraction over properties of SOAs. As shown in (13), if the adjunct is interrogative, then its INDEX represents abstraction over the corresponding type of relation (e.g. temporal or causal).

(13) a. when:

$$\left[\begin{array}{ll} \text{CONT} & \left[\begin{array}{ll} \textit{at-rel} & \\ \text{PARAM} & \left[\begin{array}{ll}\text{INDEX} & \boxed{1}\\ \text{RESTR} & \textit{time}(\boxed{1})\end{array}\right] \\ \text{SOA-ROLE} & \textit{soa}\end{array}\right]\end{array}\right]$$

b. When did John see Mary?

$$\left[\begin{array}{ll} \text{PARAMS} & \left\{\boxed{1}\left[\begin{array}{ll}\text{INDEX} & \boxed{2}\\ \text{RESTR} & \textit{time}(\boxed{2})\end{array}\right]\right\} \\ \text{SOA} & \left[\begin{array}{ll} \textit{at-rel} & \\ \text{PARAM} & \boxed{1} \\ \text{SOA-ROLE} & \left[\begin{array}{ll}\textit{see-rel} & \\ \text{SEE-ER} & \boxed{3}\\ \text{SEE-EE} & \boxed{4}\end{array}\right]\end{array}\right]\end{array}\right]$$

The framework sketched above already accommodates short answers to adjunct questions such as (14):[14]

(14) a. A: When did Jo leave?
B: At 2.

b. A: Why did Bo leave?
B: Because he was unhappy.

A bare answer to a question with an interrogative adjunct would take that adjunct as its SAL-UTT value and substitute its own relation for the latter's INDEX. In similar fashion we can also accommodate sluicing where an antecedent exists:

[14] An issue whose discussion we defer to future work concerns the categorial parallelism requirements associated with adjuncts, which appear to be somewhat freer than with arguments:

(i) A: When did Jo leave? B: At 2/Yesterday/Recently.

(15) a. A: Jo left at some point yesterday.
B: When?

b. A: Bo shot herself for a reason.
B: Hmm. Why/What?

There are, however, cases where there is no such antecedent, as in the following examples:

(16) a. A: John saw Mary.
B: When?

b. A: John likes Mary.
B: Why?

One approach we could adopt to deal with such cases is to subsume them under the analysis we give for (15). To do this, one needs to posit a mechanism of 'existential adjunct accommodation', which provides for the requisite existentially quantified antecedent. Such an approach has the advantage that it requires no extra grammatical apparatus as such, but it does involve an 'adjustment' of the content of the antecedent, which is computationally problematic in that it frequently relies on non-deterministic (specifically, abductive) principles of inference.[15]

An alternative approach, which we adopt in our current system,[16] is to take the SAL-UTT in such cases as empty (i.e. there is no parallel constituent to be picked up). Consequently, we posit an additional phrasal type *bare-soa-modifier-phrase* (*bare-soa-mod-ph*) to support the constraints needed for the interpretation of bare adjuncts. The specification for this type is as follows:

[15] From the perspective of dialogue processing this 'adjustment' can be viewed as an inference initiated by the addressee of the original utterance. Hence, it need not be viewed as *post hoc* reanalysis. This requires an approach to context, such as that developed in KOS and implemented in the GODIS system at Gothenburg (see e.g. (Bohlin et al., 1999)), in which distinct dialogue participants can diverge in their view of what constitutes the contextual common ground. Our system as it stands does not accommodate such mismatches.

[16] See (Fernández and Ginzburg, 2002a) for a similar approach to bare adjuncts.

(17) *bare-soa-mod-ph*:

$$\begin{bmatrix} \text{STORE} & \{\} \\ \text{MAX-QUD} & \begin{bmatrix} \text{PROP} \mid \text{SOA} \mid \text{NUCL } \boxed{1} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{CAT } \textit{adv} \\ \text{CONT} \begin{bmatrix} \textit{adj-rel} \\ \text{SOA-ROLE } \boxed{1} \end{bmatrix} \end{bmatrix} \end{bmatrix}$$

We posit a type *sluice-bare-adjunct-clause* (*slu-bare-adj-cl*), which is a subtype of *inter-cl* and *bare-soa-mod-ph*. This entails that it denotes a question and that the information specified for *bare-soa-mod-ph* is inherited. The sole additional information required by *slu-bare-adj-cl* concerns the semantic content of the clausal fragment and the retrieval of the index associated with the *wh*-phrase:

(18) *slu-bare-adj-cl*:

$$\begin{bmatrix} \text{CONT} & \begin{bmatrix} \textit{question} \\ \text{PARAMS } \left\{\boxed{2}\right\} \\ \text{PROP} \mid \text{SOA} \mid \text{NUCL } \boxed{1} \end{bmatrix} \\ \text{HD-DTR} & \begin{bmatrix} \text{CONT} & \boxed{1} \\ \text{STORE} & \left\{\boxed{2}\right\} \end{bmatrix} \end{bmatrix}$$

The clause's NUCLEUS is identified with the CONTENT of the head daughter and the parameter contributed by the *wh*-phrase is included in the clause's PARAMS set.

The (truncated) AVM which our system generates for the adjunct sluice *when* in (16a) is as shown in (20).

Given this treatment of adjuncts, we can also accommodate adverbial answers to polar questions such as the following:

(19) A: Was Bo sent home?
B: Probably.

Such cases are analysed as instances of a type *bare-adjunct-clause* (*bare-adj-cl*). This is a subtype of both *bare-soa-mod-ph* and *decl-cl*, which inherits its specification entirely from these two types.

(20)
$$\left[\begin{array}{ll}
\textsc{c-params} & \left\{\ldots\ \boxed{0}\ \ldots\right\} \\
\textsc{cont} & \left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{question}} \\
\textsc{params} & \left\{\boxed{0}\left[\begin{array}{ll}\textsc{index} & \boxed{1} \\ \textsc{restr} & \left\{\textit{time}(\boxed{1})\right\}\end{array}\right]\right\} \\
\textsc{prop}\,|\,\textsc{soa}\,|\,\textsc{nucl} & \boxed{2}\left[\begin{array}{ll}
\multicolumn{2}{l}{\textit{at-rel}} \\
\textsc{param} & \boxed{0} \\
\textsc{soa-role} & \boxed{3}\left[\begin{array}{ll}\multicolumn{2}{l}{\textit{see-rel}} \\ \textsc{see-er} & j \\ \textsc{see-ee} & m\end{array}\right]
\end{array}\right]
\end{array}\right] \\
\textsc{ctxt} & \left[\begin{array}{ll}
\textsc{max-qud} & \left[\begin{array}{ll}\textsc{params} & \{\} \\ \textsc{prop}\,|\,\textsc{soa}\,|\,\textsc{nucl} & \boxed{3}\end{array}\right] \\
\textsc{sal-utt} & \{\}
\end{array}\right] \\
\textsc{hd-dtr} & \left[\begin{array}{ll}\textsc{cont} & \boxed{2} \\ \textsc{store} & \boxed{0}\end{array}\right]
\end{array}\right]$$

5. Comparison with Other Approaches

The system described here shares many features with the Higher-Order Unification (HOU) account of ellipsis resolution (Dalrymple et al., 1991; Pulman, 1997). However, it differs from HOU in three important respects.

First, while HOU does not indicate how the relation of parallelism between the fragment and a counterpart term in the antecedent clause is specified, we provide an explicit definition of the counterpart term (as the phrase that supplies the value of SAL-UTT for the bare clause).[17]

Second, unlike HOU, we impose a syntactic matching condition on the category of the fragment and its counterpart term. This permits us

[17] (Gardent and Kohlhase, 1997) combine a version of HOU with an abductive calculus for computing parallel elements. This invokes relations defined over a hierarchical classification of the lexical semantics of the subconstituents, following the work of (Hobbs, 1991) on parallelism in discourse. To the best of our knowledge this system has not yet been implemented.

to rule out cases of categorial mismatch, as discussed above. Because the entire AVM of an antecedent is recoverable from the discourse record, we can invoke additional syntactic constraints on fragment interpretation if these are required (cf. (Lappin and Gregory, 1997) for other cases of ellipsis resolution where additional syntactic matching conditions are invoked).

Third, HOU is not possible when the semantic type of the target is distinct from that of the source, as when the target denotes a question and the source is a proposition or vice versa. (Pulman, 1997) attempts to bypass this problem by associating propositional contents with interrogatives. However, as the formal semantic literature on interrogatives suggests (Groenendijk and Stokhof, 1997), such a move is not semantically viable. Our system can handle such mismatches in semantic type by using the SOA and QUANTS features of different clause types present in the discourse record to specify the MAX-QUD and SAL-UTT values of a bare clause.

(Lappin and Shih, 1996) propose a generalised algorithm for ellipsis resolution, which was implemented in (Lappin and Gregory, 1997). Bare NP fragments are treated as the non-head daughters of clauses with empty heads, which are replaced in ellipsis resolution by an antecedent head. Counterpart arguments are replaced by the overt fragment, while non-counterpart arguments (and adjuncts) are copied into the ellipsis site. The present model avoids the need for empty heads and full syntactic reconstruction.

6. Conclusions and Future Work

We have presented the main features of SHARDS, a system for resolving fragments in dialogue within a typed feature structure grammar. The system provides a procedure for computing the content values of clausal fragments from contextual information contained in a discourse record of previously processed sentences.

The system has served as the basis for a variety of work on elliptical constructions. (Purver, 2004) describes an implementation of the different readings and forms of clarification requests within an TrindiKit-based dialogue system which incorporates the ellipsis resolution capability of SHARDS, together with the dialogue move engine GODIS (Cooper et al., 2001; Larsson, 2002). SHARDS has also been used as the basis of a generation module. (Ebert et al., 2004) developed an algorithm which generates full paraphrases for interpreted fragments in a dialogue management system.

The theoretical work on ellipsis resolution described in Section 2 has supported two large scale corpus studies. One focuses on the available means for posing clarification requests, of which 40% turn out to be elliptical forms (Purver et al., 2001). The other attempts to characterise the entire class of fragmentary utterances in a conversational corpus (Fernández and Ginzburg, 2002a; Fernández and Ginzburg, 2002b; Fernández and Ginzburg, 2002c). This latter study proposes a taxonomic scheme consisting of 16 classes of fragmentary utterances, a substantial part of which can be analysed within the framework described in Section 2.

Our current aim is to extend the system to cover a wider range of elliptical utterances. These include e.g. verb phrase ellipsis like (21) (see (Lappin and Gregory, 1997; Gregory and Lappin, 1999) for an analysis; see also (Nielsen, 2003) for a corpus-based study of VP ellipsis).

(21) A: Mary wants vodka.
B: Rosa does too.

Our future research is concerned with the decision procedures required for choosing the antecedent of a fragment in dialogue. In this respect, the heuristics currently employed by SHARDS select the most recent clause which is compatible with the syntactic and semantic constraints imposed by the elliptical utterance. However, to account for dialogue sequences like (22) (where the fragment phrase *to surprise you* is a reply to A's first question rather than the second), this recency measure needs to be refined.

(22) A: Why did Mary arrive early?
B: I can't tell you.
A: Why can't you tell me?
B: Okay, if you must know, to surprise you.

One of our main concerns is to develop a robust computational procedure for identifying the antecedents of fragmentary utterances, with the aim of implementing a wide coverage system for fragment interpretation in dialogue.

ACKNOWLEDGEMENTS

Earlier versions of this paper were presented at the NLP colloquium of the Cambridge Computer Laboratory (March 2000), the University College London Workshop on Syntax and Pragmatics (April 2000), the IBM Research NLP Colloquium in Hawthorne, NY (June, 2000), and the Workshop on Linguistic Theory and Grammar Implementation at ESSLLI 2000. We are grateful to the participants of these forums for useful discussion of some of the ideas in this paper. In particular we would like to thank Steve Pulman and Richard Brehny for helpful comments. This research project was funded by grant number R00022269 from the Economic and Social Research Council of the United Kingdom, by grant number AN2687/APN 9387 from the Arts and Humanities Research Board of the United Kingdom, by grant number GR/R04942/01 from the Engineering and Physical Sciences research Council, and by grant number RES-000-23-0065 from the Economic and Social Research Council of the United Kingdom.

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