Resolving Fragments Using Discourse Information

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Abstract

This paper describes an extension of RUDI, a dialogue system component for 'Resolving Underspecification with Discourse Information' (Schlangen et al., 2001). The extension handles the resolution of the intended meaning of non-sentential utterances that denote propositions or questions. Some researchers have observed that there are complex syntactic, semantic and pragmatic constraints on the acceptability of such fragments, and have used this to motivate an unmodular architecture for their analysis. In contrast, our implementation is based on a clear separation of the processes of constructing compositional semantics of fragments from those for resolving their meaning in context. This is shown to have certain theoretical and practical advantages.

1 Introduction

Non-sentential utterances that denote a proposition or a question are pervasive in dialogues. This paper describes an extension of RUDI, a dialogue system component for 'Resolving Underspecification with Discourse Information' (Schlangen et al., 2001). The extension handles the resolution of the intended meaning of such fragments in the context of scheduling dialogues. The system models the behaviour of fragments which are used to perform two types of frequently occurring speech acts: (a) question answering, as in (1); and (b) what we call question-elaboration or *Q-Elab* (following SDRT, (Asher and Lascarides, 1998)). *Q-Elab* is a subclass of questioning where all answers to the question elaborate a plan to reach the goal of a prior utterance, illustrated in (2).

(1) A: What time on Tuesday is good for you?
B: 3pm. / B′: #At 3pm. / B″: #The hotel.

(2) A: Let's meet next week.
B: (OK.) Thursday at three pm?

Our claim is that resolving the intended meaning of fragments is a by-product of establishing which speech act was performed, i.e. of establishing the *coherence* of the fragment's contribution to the dialogue. Different speech acts impose different constraints: coherent short answers must meet certain syntactic constraints (which predict B′ in (1) is incoherent) and semantic constraints (which predict B″ is incoherent), while *Q-Elab* imposes constraints on content but not on syntax.

In contrast to (Ginzburg and Sag, 2001), henceforth G&S), who incorporate contextual resolution of fragments into the grammar (see Section 4), we offer a fully compositional analysis, separating grammar from pragmatic processing. This has three advantages. First, the grammatical analysis of fragments is uniform; contextual variation in their meaning is accounted for in the same way as it is for other anaphoric phenomena, via inferences underlying discourse update. This yields the second advantage: resolving fragments is fully integrated with resolving other kinds of underspecification, such as bridging (Clark, 1975). For instance, the system resolves B in (1) to mean "3pm on [the Tuesday A was referring to] is good for B".[1] Third, it enables us to make only those semantic distinctions that are required by the dialogue-purpose. For example, the fragment in (2) will in our system be resolved with a generic $good\_time$ predicate, abstracting over possible resolutions like "How about we meet on Thursday at …?" or "Can you make Thursday at …?".

In the next section, the theoretical basis of the dynamic semantic approach realised in RUDI will be described: in a nutshell, an (underspecified) compositional semantic representation of the current clause is constructed (see Sections 2.1 and 2.2), which is used to update the representation of the discourse context. The co-dependent tasks of computing speech acts and goals and resolving semantic underspecification are tackled as a by-product of computing this update. For this, we use Segmented DRT (SDRT, (Asher and Lascarides, in press)), where *update* computes the pragmatically preferred interpretation (see Section 2.3.1). This is formulated within a precise nonmonotonic logic,

[1] Details on the resolution of bridging relations can be found in (Schlangen et al., 2001); we focus here on the new treatment of fragments.

in which one computes the *rhetorical relation* (or equivalently, the speech act type) which connects the new information to some antecedent utterance. This speech act places constraints on content and possibly even on the form of their arguments, and also on the goals of the utterances; these constraints serve to resolve semantic underspecification (Section 2.3.2). In Section 3 we then describe how this formalisation is implemented in our computer program, and we give a worked example. We conclude with a comparison with related work (Section 4), and with an outlook on further work (Section 5).

2 Theory

2.1 A Compositional Semantics for Fragments

For compositional semantic analysis we use Minimal Recursion Semantics (MRS, (Copestake et al., 1999)), a language in which (sets of) formulae of a logical language (the *base language*) can be *described* by leaving certain semantic distinctions unresolved. This is achieved via a strategy that has become standard in computational semantics (e.g., (Reyle, 1993)): one assigns labels to bits of base language formulae so that statements about their combination can be made in the 'underspecification' language. The (first-order) models of formulae of this latter language then can be seen as standing in a direct relation to formulae of the base language; $M \models \phi$ then means that the base-language formula corresponding to M is described by the MRS ϕ.[2] By way of example, (3) shows an MRS-representation of "Everyone loves someone", where so called elementary predications (EPs) are labelled with *handles* (h_n), with h being the top handle that outscopes all others; '$h_1 =_q h_2$' stands for an 'outscopes' relation between EPs where only quantifiers can be scoped in between h_1 and h_2; *prpstn_rel* signals that the MRS describes a proposition.

(3) $$\begin{array}{l}\langle h, e, \{h\!:\!prpstn\_rel(h_1), h_2\!:\!love\_v\_rel(e, x_1, x_2),\\ \quad h_6\!:\!\_every\_rel(x_1, h_8, h_9),\\ \quad h_{10}\!:\!\_person\_rel(x_1),\\ \quad h_{11}\!:\!\_some\_rel(x_2, h_{12}, h_{13}),\\ \quad h_{14}\!:\!\_person\_rel(x_2)\},\\ \{\ h_1 =_q h_2, h_8 =_q h_{10}, h_{12} =_q h_{14}\ \}\rangle\end{array}$$

The compositional semantics of fragments leaves more information unresolved than just semantic scope, however. All we know about the meaning of fragments like those in (1) and (2) independent from their context is: (a) they will resolve to a proposition or a question respectively, of which (b) the main predicate is unknown, but (c) one participant in the main event is specified although its exact role isn't. We represent this with an anaphoric relation *unknown_rel*, and so the NP-fragment "3 pm" (regardless of the context it stands in) is represented as:

(4) $$\begin{array}{l}\langle h, e, \{h\!:\!prpstn\_rel(h_1),\\ \quad h_2\!:\!unknown\_rel(e, x),\\ \quad h_6\!:\!def\_rel(x, h_8, h_9),\\ \quad h_{10}\!:\!numbered\_hour\_rel(x, 15)\},\\ \{\ h_1 =_q h_2,\ h_8 =_q h_{10}\ \}\ \rangle\end{array}$$

The *unknown_rel* acts as a 'place-holder' for a potentially complex sub-formula; more precisely it is a constraint on the form of the described (base-language) formulae, namely that they contain at this place a subformula, which in the case of (4) must have e and x amongst its variables. It is important to note that *unknown_rel* is *not* a second order variable, and it is *not* something that simply gets replaced by a predicate symbol of the same arity. Rather, *unknown_rel* is a constraint more like the $=_q$-constraints, constraining the form of the described formulae. It is anaphoric, because the subformula that is to be inserted at this point in the described formula is not known by the grammar, but must be provided by the context. Procedurally, the relation can simply be understood as a signal for attention to a resolution mechanism; we will describe this mechanism below in Section 3.

PP-fragments differ only in that a further relation (corresponding to the preposition) is present. We implemented our semantic analysis within the wide-coverage English Resource Grammar (ERG, see `http://lingo.stanford.edu`), in which functional prepositions like that in (5) are represented in the MRS, even though they might eventually translate into the trivial (i.e., always true) predicate $\top$ in the base language.[3]

(5) A: On what time did we agree for the meeting? — B: On 3 pm.

We exploit this feature here, representing B's reply in (5) as shown in (6). Note that the handle of the EP corresponding to the preposition is constrained to be subordinate to that of the *unknown_rel* (i.e. $h_2 \leq h_3$), not just $=_q$. This is because this *unknown_rel* can resolve to a complex formula containing not only the predicate for the phrasal verb that selects for *on*, but possibly also other scope-

[2] The authors do not provide such a semantics for MRSs in (Copestake et al., 1999), but it is relatively straightforward to do so, for example along the lines of (Egg et al., 2001), or, as we use in our system, (Asher and Lascarides, in press). Also note that we do not make any assumptions about the base language and its logic here; the descriptions are compatible with it being static first order predicate logic, or a dynamic logic like DRT (Kamp and Reyle, 1993).

[3] This is independently motivated because it makes the grammar monotonic (i.e., every lexical item introduces an EP, and the LF of a mother-node contains all those of its daughters), a property that is desirable for generation (Shieber, 1986). We will make use of this feature below in section 2.3.

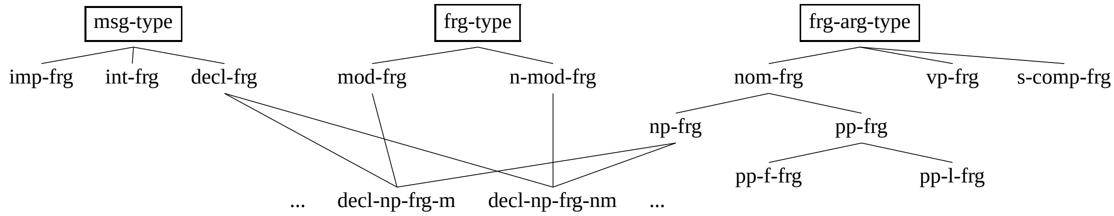


Figure 1: An extract of the construction hierarchy for fragments

bearing elements that aren't quantifiers, eg. in the context of a question like "what time might Peter agree on?".

(6) $$\begin{array}{l}\langle h, e, \{h\!:\!prpstn\_rel(h_1),\\ \quad h_2\!:\!unknown\_rel(e,x),\\ \quad h_3\!:\!\_on\_rel\_s(e',x),\\ \quad h_6\!:\!def\_rel(x,h_8,h_9),\\ \quad h_{10}\!:\!numbered\_hour\_rel(x,15)\ \},\\ \{\ h_1 =_q h_2, h_8 =_q h_{10}, h_2 \leq h_3\}\ \rangle\end{array}$$

2.2 A Grammar of Fragments

The grammar rules that produce these MRSs are relatively straightforward. Fragments are treated as phrases,[4] possibly modified by adverbs. As (7) shows, only scopally modifying adverbs are allowed.

(7) A: When shall we meet?
B: Maybe at 3 pm on Sunday. / *Quickly at 3pm on Sunday.

We will allow both sentential modification, where an adverb attaches to an S[*frag*], and 'VP'-modification, where the adverb is selected by the fragment rule (eg. "not 3pm"). Semantically, the difference amounts to whether the whole proposition (which is to be resolved) is modified or only the *unknown_rel*.

In a pseudo phrase-structure notation, the rules are of the form 'S-frag → (ADV) XP'. We formalise this in a version of HPSG that allows *constructions* (Sag, 1997), i.e. phrase-types that make a semantic contribution. The fragment-signs are organised along three dimensions, as shown in Figure 1: the message type, i.e. whether they resolve to a proposition, a question or a request; whether they are modified by an adverb or not; and what the type of the argument is (i.e., whether it's for example an NP-fragment or a PP-fragment).

Figure 2 gives an NP-fragment sign in a tree-style notation. It shows how the CONTent of the fragmental sentence (an MRS in AVM notation) is a combination of the contribution of the construction (C-CONT) and the content of the fragment-phrase, with the index of that phrase ($\boxed{5}$) being the argument to the *unknown_rel* coming from C-CONT.

Note that since the semantic representations do not need any information about the context of the utterance, the grammatical rules do not need to assume any additional machinery that is not independently motivated in the ERG. Further, since these rules are implemented in a wide-coverage grammar they are shown to be compatible with the analyses of a wide variety of linguistic constructions.

2.3 Discourse Update and Resolution of Underspecification

2.3.1 SDRT

As we said earlier, we use SDRT to compute the pragmatically preferred update of the context with new utterances. The co-dependent tasks of computing speech acts and goals and resolving semantic underspecification are tackled as a by-product of computing this update. This update is formulated within a precise nonmonotonic logic, in which one computes the *rhetorical relation* (or equivalently, the speech act type) which connects the new information to some antecedent utterance. This speech act places constraints on content and possibly even on the form of their arguments, and also on the so-called *speech act related goals* or SARGs (these are the goals which are conventionally associated with utterances of various forms; see (Asher and Lascarides, 1998) for details). These constraints serve to resolve semantic underspecification.

The rhetorical relations which are relevant here are:[5] *Q-Elab*(α, β), Question Elaboration, where β is a question where any possible answer to it elaborates a plan for achieving one of the SARGs of α, as in (2); and *IQAP*(α, β), Indirect Question Answer Pair, where α is a question and β conveys information from which the questioner can infer a direct answer to α, as in (1).[6] Note that these speech

[4] This goes back to (Morgan, 1973); explicit rules can be found in (Barton, 1990). We ignore for now more complicated examples like 'A: Does John devour or nibble at his food? — B: Oh, John devours.'

[5] RUDI computes other speech acts as well, such as *plan-correction* and *plan-elaboration*, but currently only for full sentences and not for fragments.

[6] We only look at fragments that are *direct* answers here; this is a subclass of *IQAP* where the direct answer follows trivially from β.

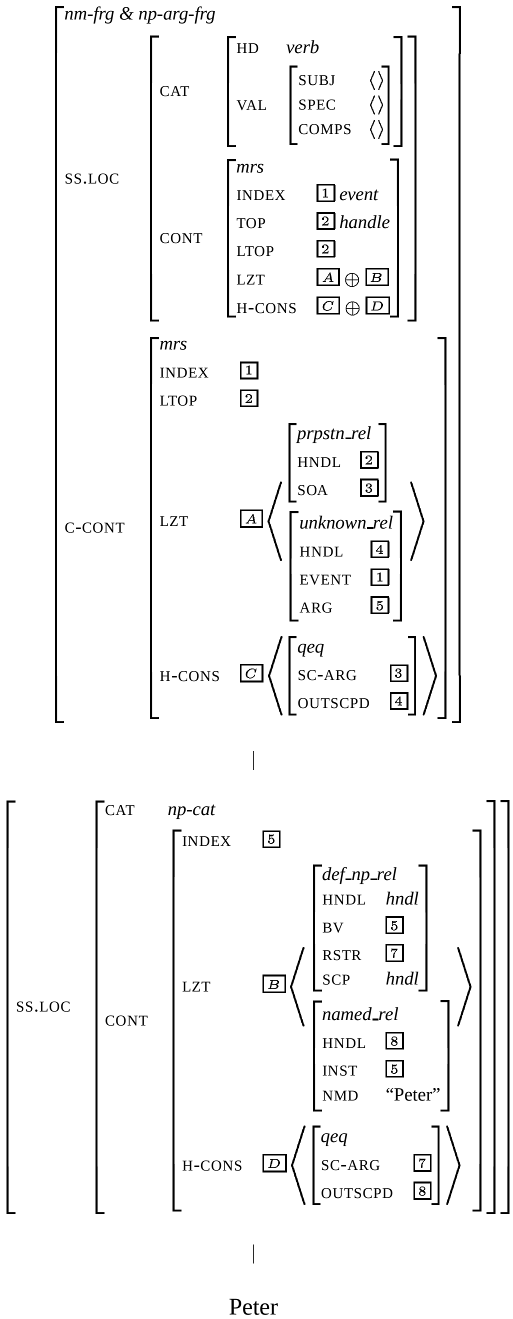


Figure 2: "Peter" as a declarative fragment.

act types are *relations* (cf. (Searle, 1967)), to reflect that the successful performance of the current speech act is logically dependent on the content of an antecedent utterance (e.g., successfully performing the speech act *IQAP*, as with any type of answering, depends on the content of the question α).

These speech acts are computed via default rules; those for *Q-Elab* and *IQAP* are given below. In these rules, $\langle \tau, \alpha, \beta \rangle$ means β is to be attached to α with a rhetorical relation (α and β label bits of content) where α is part of the discourse context τ; α :? means that α is an interrogative, and $A > B$ means *If A then normally B*:[7]

(8) `Q-Elab`: $(\langle \tau, \alpha, \beta \rangle \wedge \beta :?) > \textit{Q-Elab}(\alpha, \beta)$
`IQAP`: $(\langle \tau, \alpha, \beta \rangle \wedge \alpha :?) > \textit{IQAP}(\alpha, \beta)$

`Q-Elab` stipulates that the default role of a question is to help achieve a SARG of a prior utterance. `IQAP` stipulates that the default contribution of a response to a question is to supply information from which the questioner can infer an answer. Thus inferences about speech acts, and hence about implicit content and goals, can be triggered (by default) purely on the basis of sentence moods.

One main tenet of SDRT is that it is desirable to separate the logic of information content from that of information *packaging* (the logic in which constructing logical form takes place), because the former will be at least a first-order language, and hence undecidable, whereas constructing logical forms should be a decidable undertaking (Asher and Lascarides, 1998 & in press). MRSs can be seen as part of the latter logic. Since the underspecification arising from fragments can be resolved on this description level, we are only concerned here with MRSs and can neglect the DRSs they are meant to describe in this theory.

2.3.2 Fragmental Questions and Answers

We now address resolving the underspecification indicated by *unknown_rel*. In particular, we argue that there are certain constraints on the *form* of fragments that stand in an *IQAP*-relation to a prior utterance, whereas *Q-Elab*-fragments need satisfy only *semantic* constraints. These different constraints can be motivated with a look at the semantics of the speech acts given above. *Q-Elab*s constrain their arguments on the level of discourse plans, i.e. on a purely semantic level, whereas *IQAP*s connect the utterances in a tighter way, given the semantics of answerhood with its function-application aspect. Note that these constraints are not mutually exclusive, and so an utterance can stand in both of these relations to the context.

Syntactic Parallelism in Fragmental Answers We begin with a look at complement questions like (9) below. Intuitively, one can say that there is a 'hole' in such questions, marked syntactically by the *wh*-phrase and semantically by a variable (be that bound by a λ-operator, as in (Groenendijk and Stokhof, 1984) or by a quantifier, as in the ERG).

[7](Asher and Lascarides, 1998) show that these rules can be derived from a precise model of rationality and cooperativity.

(9) A: What date did we agree on for the meeting?
B: Not (on) next Monday.

This initially suggests that to resolve the content of the fragment, one could attempt to do syntactic reconstruction, 'plugging' the syntactic structure of the fragment into the (syntactic) 'hole' in the question (cf. (Morgan, 1973)). Unfortunately, as G&S attest, such a strategy fails for some cases; eg. for (9) above: "we agreed on not next Monday for the meeting." is not a well-formed sentence.

On the other hand, G&S also attest that a purely semantic reconstruction, where the semantic representation of the fragment is 'plugged into' the (semantic) 'hole' in the question, is also unsatisfactory. Certain grammatical idiosyncrasies seem to persist beyond sentence boundaries. This can also be shown with (9). The preposition in the question is generally considered to be semantically empty and to only serve a grammatical function. Nevertheless, only this particular semantically empty preposition can occur in a fragmental answer to this question (although it is optional). If all we have is a logical form of the fragment phrase, we cannot express this restriction on the *form* of that phrase.[8] Moreover, we couldn't rule out such functional PPs as answers to NP-questions, since these PPs are not distinguishable semantically from NPs.

Another English example with which this syntactic parallelism can be shown is (10) (from G&S, p.300). Here the fragmental answers must be of the syntactic category required by the verb in the question (VP[*bse*] and VP[*inf*], respectively), even though the semantic objects denoted by these VPs presumably are of the same type.[9]

(10) a. A: What did he make you do?
B: Sing
b. A: What did he force you to do?
B: To sing.

We can now formulate a preliminary version of the constraint on fragmental *IQAP*s:[10]

(11) `IQAP-frag:` $\mathit{IQAP}(\alpha,\beta) \wedge \mathit{frag}(\beta) \rightarrow \mathit{syn\text{-}par}(\alpha,\beta) \wedge \mathit{resolve}(\alpha,\beta)$

In words, if a fragmental utterance β answers an antecedent question α, then a certain (yet to be specified) syntactic-parallelism has to hold between α and β (note that this means that syntactic information must be accessible to this rule), and the semantic information contained in α must be sufficient to resolve the underspecification in β.

G&S set up the syntactic parallelism as identity of category between *wh*-phrase and fragment-phrase. However, this analysis cannot be straightforwardly extended to questions where the *wh*-phrase is an adjunct rather than a complement, such as "When shall we meet?". The *wh*-phrase of this question is a PP and yet acceptable short answers to it include NPs such as "three pm". Further, it seems questionable to stipulate that the *wh*-phrase in a question like "what time should we meet at?" (which can be answered with a PP-fragment) is syntactically a PP. Thus strict identity of syntactic category of question and answer seems too strong. We will realise the syntactic parallelism with a combined syntactic / semantic constraint on resolved fragments, as described in Section 3. Our analysis of short answers to both complement-questions (e.g., "What time did we agree on?") and adjunct-questions (e.g., "When did we agree to meet?") will be uniform.

One use of Fragmental Questions Fragmental questions can be used to help further the purpose of a dialogue: (12) gives examples of successful and of unsuccessful fragmental *Q-Elab*s.

(12) A: Let's meet next week.
B: (OK.) Monday? / On Monday? / #3 pm? / #Peter? / #Week 3 of term?

To rule out the infelicitous replies in (12) we do not need to look at the *form* of the antecedent; complying with the *semantic* constraints imposed by *Q-Elab* is enough. In this domain, the speech act related goal of an utterance α is to identify a time to meet within some time interval (which we call SARG_α). So if a question β proposes a time t_β that is included in SARG_α (i.e., $temp\_inc(\text{SARG}_\alpha, t_\beta)$ holds), then all answers to β will elaborate a plan to achieve α's goal, as required: some answers restrict the search to t_β; while the others rule out t_β from the search. Hence, the only constraint on *Q-Elab* we need here is the following (see (Schlangen et al., 2001) for further details of the interplay between speech acts, semantics and goals):

(13) `Q-Elab:`
$\mathit{Q\text{-}Elab}(\alpha,\beta) \rightarrow \mathit{temp\_inc}(\text{SARG}_\alpha, t_\beta)$

All the infelicitous replies in (12) are now ruled out: the first because of uniqueness constraints on antecedents to anaphoric definites like "3pm"; the second because it can't resolve to a question which satisfies the constraint (13). "Week 3 …" is also

[8] As we said earlier, such semantically empty prepositions are in fact represented in the MRSs produced by the ERG; MRSs however are *descriptions* of logical forms, and keeping these empty prepositions in is a way of retaining syntactic information. We will exploit this in the resolution strategy described below.

[9] For a further discussion of the exact extent of this parallelism see (Schlangen, 2002).

[10] Given the semantics of the relation *resolve* explained below, *IQAP*-fragments are all direct answers.

ruled out as a *Q-Elab*, since the time interval referred to is *identical* to the SARG of the antecedent. It is nevertheless a coherent reply, standing in a relation of *Clarification* to A's utterance, which we do not deal with in this paper. G&S analyse clarification questions, but to distinguish between this speech act and the speech act of *Q-Elab* would require them to complicate their *grammatical* analysis considerably.[11]

3 Implementation

3.1 Overview of the system

Reflecting the modularity of the underlying theory, RUDI divides the update process into several stages. We only give a brief overview of the system here, referring the interested reader to (Schlangen et al., 2001) for details on the algorithm. We have made some changes to the set-up (besides adding resolution of fragments), though, which will be described in some more detail below.

The structure of the system is shown schematically in Figure 3. The input to the system are MRSs coming out of the grammar. As mentioned above, we have modified a wide-coverage HPSG (the ERG) to produce representations for fragments as well. The changes required for our analysis of fragments were moderate, about one hundred lines of code in a grammar comprising several tenthousand lines. This grammar is executed by a parser, the LKB (Copestake, 2002). The initial stage adds to the MRS of the chosen ERG-parse predicates which abstract away from certain semantic details, for example about which actions permit meeting at a certain time and which don't. At the next stage, an utterance in the context is chosen to which the current one can be attached via a rhetorical relation, and this in turn determines which antecedents are available. The preference is to attach to the prior utterance; this default is derivable in the logic of SDRT from assumptions about cooperativity and rationality, but since this derivation is context-independent, the preference is hard-coded here.

The speech act(s) of the current utterance is (are) then inferred non-monotonically from information about the antecedent and the current utterance and axioms like those given above for *IQAP* and *Q-Elab*. Here we deviate from (Schlangen et al., 2001), where we explored to what extent we can make the reasoning about speech-acts monotonic. We decided that for further extensions we need to fully implement the non-monotonic theory specified by SDRT. For this we implemented an automated theorem prover for the fragment of the nonmonotonic logic (Common Sense Entailment) employed in SDRT to compute rhetorical relations. (For details about the theorem prover see (Schlangen and Lascarides, 2002).) The rules (8) for inferring *IQAP* and *Q-Elab* given above can be passed directly to this theorem prover.

The next module, `sa_cnstr`, tests whether the monotonic constraints on the speech acts (for our application, these are given by the rules (11) and (13)) are all satisfied. After satisfying the constraints the SARGs are computed and any remaining underspecification is resolved; in a last step, the context is updated with the resolved representation of the current utterance.

3.2 A Worked Example

We illustrate how fragmental *IQAP*s are resolved in the system with example (1) from the introduction, repeated here as (14). The MRS-representation of the question is shown in (15); that of reply B was already given above in (4).

(14) A: What time on Tuesday is good for you?
B: 3pm. / B′: #At 3pm.

(15)
$$\begin{array}{l}\langle h_1, e_2, \{h_3 : \_which\_rel(x6, h_7, h_5),\\ \quad h_8 : \_time\_rel(x_6),\\ \quad h_8 : \_on\_temp\_rel(e_{11}, x_6, x_13),\\ \quad h_{14} : dofw\_rel(x_{13}, "TUE"),\\ \quad h_{16} : def\_np\_rel(x_{13}, h_{17}, h_{18}),\\ \quad h_{20} : \_good\_rel(e_2, x_6),\\ \quad h_{20} : \_for\_rel(e_{22}, e_2, x_{24}),\\ \quad h_{25} : pron\_rel(x_{24}),\\ \quad h_{26} : def\_rel(x_{24}, h_{27}, h_{28}),\\ \quad h_1 : int\_rel(h_{32})\},\\ \{ h_7 =_q h_8, h_{17} =_q h_{14},\\ \quad h_{27} =_q h_{25}, h_{32} =_q h_{20}\}\rangle\end{array}$$

In the implementation, the two predicates *syn-par* and *resolve* from constraint (11) are combined into one predicate `resolve` which is computed in three steps: first, the question MRS is transformed into a "λ-abstract", or equivalently, the subformula that will fill the position indicated by the *unknown_rel* is identified, see (16-a); second, this is "applied" to the fragment meaning (i.e., the replacement is made), see (16-b) (the added material is printed indented; h_2 and h'_{20}, e and e'_2, and x and x'_6 are identified); and third, the well-formedness of the result is checked.

This well-formedness constraint is *not* a test for parallelism between wh- and fragment-phrase (see earlier discussion). Rather, we check whether we can "assemble" a well-formed MRS from both utterances: it must be possible to partition the result-

[11]In fact, we do not have a speech act *Clarification* as such in our theory, but rather model the semantic effect of such utterances by a combination of *Elaboration* and *Q-Elab*. The kind of clarifications G&S analyse, namely those where the *content* of the previous utterance is being clarified (rather than the intention behind making it), do exhibit syntactic parallelism like the short-answers discussed above. Eg. "Peter relies on Sandy. — On whom?". Such utterances are *also Q-Elab*s, but the syntactic constraints are on the speech act *Elaboration*.

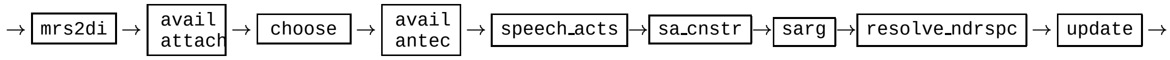


Figure 3: Flowchart of the algorithm

ing MRS so that all partitions are semantic representations for verb-relations, their arguments or possibly their adjuncts. This is the case for our example, as the reader is invited to check. It wouldn't be for answer B' from (14), because here the fragment brings with it a relation corresponding to a preposition that isn't matched in the material coming from the question.

(16) a.
$$\{\ h_8 : \_on\_temp\_rel(e_{11}, \mathbf{x_6}, x_13),\ h_{14} : dofw\_rel(x_{13}, "TUE"),\ h_{16} : def\_np\_rel(x_{13}, h_{17}, h_{18}),\ h_{20} : \_good\_rel(\mathbf{e_2}, \mathbf{x_6}),\ h_{20} : \_for\_rel(e_{22}, \mathbf{e_2}, x_{24}),\ h_{25} : pron\_rel(x_{24}),\ h_{26} : def\_rel(x_{24}, h_{27}, h_{28})\ \}$$

b.
$$\{\ h' : prpstn\_rel(h'_1),\ \mathbf{h'_2} : unknown\_rel(\mathbf{e}, \mathbf{x}),\ \mathbf{h_{20}} : \_good\_rel(\mathbf{e'_2}, \mathbf{x'_6}),\ \mathbf{h_{20}} : \_for\_rel(e'_{22}, \mathbf{e'_2}, x'_{24}),\ h_8 : \_on\_temp\_rel(e'_{11}, \mathbf{x'_6}, x'_{13}),\ h_{14} : dofw\_rel(x'_{13}, "TUE"),\ h_{16} : def\_np\_rel(x'_{13}, h_{17}, h_{18}),\ h_{25} : pron\_rel(x'_{24}),\ h_{26} : def\_rel(x'_{24}, h'_{27}, h'_{28}),\ h'_6 : def\_rel(x, h'_8, h'_9),\ h'_{10} : numbered\_hour\_rel(x, 15)\},\ \{\ h'_1 =_q h'_2,\ h'_8 =_q h'_{10}\ \}\ \rangle$$

This formulation of the well-formedness condition relies on two features of the ERG: first, adjunct questions introduce an underspecified preposition-relation in the MRS, as seen in (17); second, as already mentioned, all lexical items, including semantically empty ones, introduce an EP. This means that in effect we use the syntactic information contained in the MRSs to model the syntactic parallelism G&S noted. This seems to work for English, and makes our implementation relatively simple. We stress here though that this is not a crucial point of the underlying *theory*, which simply demands that some syntactic information is accessible to constraint (11). We discuss other approaches that use such mixed syntactic and semantic representations below in Section 4.

To give another example, "on Monday" is accepted as an answer to "when shall we meet?" (see (17) below) because after applying the question to the fragment, the variable that denotes the Monday will be argument of the *unspec_loc_rel* introduced by "when". The well-formedness constraint involving partitions above forces this underspecified relation to resolve to the EP corresponding to the "on" from the answer.

Our approach predicts that a question like "what

(17)
$$\langle h_1, e_2, \{h_1 : int\_rel(h_{20}),\ h_{15} : meet\_rel(e_2, x_{10}),\ h_{15} : unspec\_loc\_rel(e_2, x_4),\ h_5 : which\_rel(x_4, h_8, h_7),\ h_3 : temp\_rel(x_4),\ h_{11} : def\_rel(x_{10}, h_{12}, h_{13}),\ h_9 : pron\_rel(x_{10})\},\ \{\ h_{20} =_q h_{15}, h_8 =_q h_3, h_{12} =_q h_9\}\ \rangle$$

did we agree on?", where there is a functional preposition in the question, can be answered both with a PP-fragment, in which case the two preposition-rels are equated, and with just an NP-fragment, which is β-reduced into the argument-position of the preposition. PPs (both with functional and with lexical prepositions) are ruled out as answers to NP-questions because there the well-formedness check fails, since there is no preposition-rel in the question that would match that in the answer.

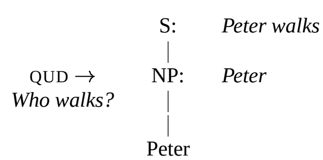
We turn now to the resolution of *Q-Elab*s. As explained above, there is no specific constraint for fragmental realisations of *Q-Elab*s, and so in an example like (18) only the temporal expression is resolved, in the way explained in (Schlangen et al., 2001). B$'$ in the example below is predicted to be incoherent simply because it doesn't provide a temporal expression.

(18) A: Let's meet next week.
B: Tuesday? / B$'$: #Peter?

4 Related Work

As mentioned in the introduction, G&S offer a non-modular approach to the resolution of short-answers (and some other fragmental speech acts). (19) shows a very schematic representation of their approach.

(19)



A grammar rule specific to short-answers directly projects NPs as sentences, with parts of the sentential content coming from a contextual feature QUD (question under discussion). This grammar rule in one go checks the syntactic parallelism and constructs the intended content of the fragment.

We have already given some features that we see as advantages of separating these different tasks above (see Section 1). From a practical perspective, it seems that a non-modular approach also leads to certain complications. The system described in (Ginzburg and Gregory, 2001), an implementation of G&S, performs unification-operations on (syntactic) representations coming out of the grammar to insert the contextual information *a posteriori*. This means that no standard off-the-shelf parsers can be used in their system.

Another strand of related work concerns the phenomenon of parallelism, which has been studied for a range of both intra- and intersentential constructions; for instance coordination, VP-ellipsis and discourse structure (see references in (Prüst et al., 1994)). (Prüst et al., 1994) deals with the problem of computing which elements of clauses are to be considered parallel on the level of content. The parallelism-constraints in CLLS (Egg et al., 2001) make sure that certain scope-decisions in one representation are tied to that in another representation. Both these notions are complimentary to ours, which concerns certain *syntactic* features of parallel elements. Closest in spirit is (Kehler, 2002), where the question of whether syntactic features play a role is relativised to the speech act.

Interestingly, all theses approaches used mixed syntactic/semantic-representations similar to the one we use in our system. (Prüst et al., 1994) retain information about constituency in their representations (as does (Asher, 1993)), while (Kehler, 2002) keeps all syntactic information to allow reconstruction of syntactic structure. Our proposal lies somewhere in the middle, with some syntactic features above and beyond constituency being required to persist, while others are not being carried over from grammar.

Mixed representations have also been motivated on more practical grounds, for example in (McRoy et al., 1998) and (Milward, 2000), because they support more robust techniques of processing natural language. Their representation formats seem to contain enough information to be useful for our system as well; this is something we might explore in the future.

5 Conclusion and Further Work

We have offered a compositional semantics of fragments and constraints on two speech acts that can be performed with them. We have described how a dialogue system can use these constraints to resolve the intended meaning of fragments. We also have discussed why we think this approach has certain advantages compared to others (eg. G&S). In future work, we will extend the system to cover other speech acts that can be performed with fragments, for example *Elaboration* and *Correction*. We also intend to evaluate the system on a larger scale, by running corpus examples through it.

References

N. Asher and A. Lascarides. 1998. Questions in dialogue. *Linguistics and Philosophy*, 23(2):237–309.

N. Asher and A. Lascarides. in press. *Logics of Conversation*.

N. Asher. 1993. *Reference to Abstract Objects in Discourse*. Kluwer Academic Publisher, Dordrecht.

E. L. Barton. 1990. *Nonsentential Constituents*. John Benjamins, Amsterdam / Philadelphia.

H. Clark. 1975. Bridging. In R. Schank and B. Nash-Webber, editors, *Theoretical Issues in Natural Language Processing*. MIT Press.

A. Copestake, D. Flickinger, I. Sag, and C. Pollard. 1999. Minimal recursion semantics: An introduction. Stanford University, Stanford, CA.

A. Copestake. 2002. *Implementing Typed Feature Structure Grammars*. CSLI publications.

M. Egg, A. Koller, and J. Niehren. 2001. The constraint language for lambda structures. Journal of Logic, Language, and Information. To appear.

J. Ginzburg and H. Gregory. 2001. SHARDS: Fragment Resolution in Dialogue. In H. Bunt, I. van der Silius, and E. Thijsse, editors, *Proceedings of the 4th International Conference of Computational Semantics*, pages 156–172, Tilburg, The Netherlands.

J. Ginzburg and I. A. Sag. 2001. *Interrogative Investigations: The Form, Meaning, and Use of English Interrogatives*. Number 123 in CSLI Lecture Notes. CSLI Publications, Stanford.

J. Groenendijk and M. Stokhof. 1984. *Studies on the Semantics of Questions and the Pragmatics of Answers*. Ph.D. thesis, University of Amsterdam, Amsterdam.

H. Kamp and U. Reyle. 1993. *From Discourse to Logic*. Kluwer, Dordrecht.

A. Kehler. 2002. *Coherence, Reference, and the Theory of Grammar*. CSLI Publications.

S. W. McRoy, S. S. Ali, and S. M. Haller. 1998. Mixed depth representations for dialog processing. In *Proceedings of the Cognitive Science Society 1998*.

D. Milward. 2000. Distributing representation for robust interpretation of dialogue utterances. In *Proceedings of the Association for Computational Linguistics 2000*.

J.L. Morgan. 1973. Sentence fragments and the notion 'sentence'. In *Issues in Linguistics*. UIP, Urbana.

H. Prüst, R. Scha, and M. van den Berg. 1994. Discourse grammar and verb phrase anaphora. *Linguistics and Philosophy*, 17:261–327.

U. Reyle. 1993. Dealing with ambiguities by underspecification. *Journal of Semantics*, 10:123–179.

I. A. Sag. 1997. English relative clause constructions. *Journal of Linguistics*, 33(2):431–484.

D. Schlangen and A. Lascarides. 2002. CETP: An automated theorem prover for a fragment of common sense entailment. Informatics Research Report EDI-INF-RR-0119, Edinburgh University.

D. Schlangen, A. Lascarides, and A. Copestake. 2001. Resolving underspecification using discourse information. In P. Kühnlein, H. Rieser, and H. Zeevat, editors, *Proceedings of BI-DIALOG 2001*, pages 79–93, Bielefeld, June.

D. Schlangen. 2002. A compositional approach to short answers in dialogue. In G. Mann and A. Koller, editors, *Proceedings of the Student Research Workshop at the 40th ACL*, Philadelphia, USA, July.

J. Searle. 1967. *Speech Acts*. CUP.

S. Shieber. 1986. *An Introduction to Unification-based Approaches to Grammar*. CSLI publications.