Bridges Between Events. Indirect Reference to Eventualities

Matthias Irmer
University of Leipzig
mirmer@uni-leipzig.de

1 Introduction

Natural language discourses consisting of several utterances are more than merely stringing the utterances together. Discourses are structured and there are relations between utterances at various levels. Basically, one can distinguish coherence and cohesion in a discourse. On the one hand, text segments are connected by discourse relations, yielding coherence of a discourse. On the other hand, there are lots of anaphoric relations in one utterance and spanning even bigger distances. They are responsible for cohesion in a text. Various types of anaphora can be distinguished - they can be direct, e.g. if a pronoun is used, or more indirect, if there is some connection but no direct coreference between discourse entities. These cases of anaphora are called bridging anaphora (Clark, 1977).

There is some literature about bridging anaphora concerning indirect reference to previously introduced discourse entities (Asher and Lascarides, 1998a; Piwek and Krahmer, 2000, a.o.). But there is very little work done on bridging relations involving reference to abstract entities such as eventualities. Danlos (2001) accounts for the special case of event coreference. In this paper, we want to investigate indirect bridging relations between events.

This paper is organized as follows. In section 2, we will introduce bridging references to eventualities and summarize the current account of bridging in the SDRT framework. In section 3 then, the basic ideas of frame semantics and FrameNet are introduced. In section 4, we will try to integrate FrameNet and SDRT. Section 5 shows how bridging references can be solved using the proposed account, before we conclude in section 6.

2 Bridging Anaphora

2.1 Bridges between Events

(1) a. John was murdered yesterday.

b. The knife lay nearby.

Utterance (1a) describes a killing event which took place on the day preceding the utterance. The individual referred to by the proper name "John" is the victim of the event. Utterance (1b) describes a state of the entity denoted by the definite noun phrase "the knife"[1]. This entity is new in the discourse, but stands in an implicit relation to the event described in utterance (1a): the knife served probably as the instrument of the killing event. This relationship is not expressed by linguistic means. Instead, the hearer has to infer it using contextual knowledge. Apart from understanding the previous utterance, successful interpretation of (1b) requires some world knowledge: in a murdering event, there must be a victim and a killer, and normally there is also an instrument used for performing the act.

[1] Although the most obvious cases of bridging inferences are triggered by definite descriptions, there are also cases of referring indefinite noun phrases which convey a bridging relation. In (2), "a knife" clearly refers to the probable instrument of murdering, almost identically as in example (1). We will concentrate on utterances involving definites, and we will indicate different behaviour of indefinites whenever necessary.

(2) John was murdered yesterday. A knife lay nearby.

Only by means of this additional knowledge, the hearer can successfully interpret the utterance and connect it to the preceding discourse. In this way, interpretation involves constructing incrementally a structured mental representation of the discourse. It is structured in the sense that rhetorical relations hold between discourse segments. In example (1), utterance (b) is subordinated to (a), providing background information. Neither these relations between utterances nor relations between discourse entities (including eventualities) have to be expressed necessarily directly by linguistic means. Often they exist only implicitly, forcing the hearer to infer them using defeasible pragmatic inferences.

In a successful interpretation, all information, not only directly expressed but also indirectly inferred, will be part of the discourse model constructed by the hearer in course of interpretation. The discourse model, as Cornish (1999) puts it, is "a constantly evolving representation of the entities, propositions, eventualities, properties, and states, as well as their interrelations, which are introduced into the discourse, or are assumed already to exist therein, at particular points".

Most of the current theories of discourse structure make use of a notion of discourse relations. In this paper, we will adopt Segmented Discourse Representation Theory (SDRT, Asher and Lascarides, 2003).

2.2 Bridging in SDRT

We assume that the reader is familiar with the basics of dynamic semantics (DRT, Kamp and Reyle, 1993). SDRT is an extension of DRT with basically two new expressions: (i) speech act discourse referents which label content of text segments and keep track of token utterances, and (ii) rhetorical relations which relate speech act discourse referents. The resulting structures are segmented DRSs (SDRSs).

In SDRT, bridging inferences are seen as "a byproduct of computing how the current sentence connects to the previous ones in the discourse" (Asher and Lascarides, 1998a). Four meta-rules for bridging are stated:

1. **If possible use identity.**
2. **Bridges must be plausible.**
3. **Discourse structure determines bridging.**
4. **Maximize discourse coherence.**

The first rule reflects the empirical preference of resolving anaphora to an identical antecedent. This rule is the preferred rule; if resolution to identity is not possible, then the other rules apply in the indicated order. The second rule means that world knowledge "specifies certain plausible ways of filling the underspecified parameters in the presupposed material". Thus, plausibility relies on world knowledge, but is not defined precisely. We will try to refine this notion in a more constrained way. The third rule says that if a rhetorical relation between the discourse segments involved gives particular clues for resolving the anaphora, then this information is to be used. The forth rule is one of the most basic principles assumed in SDRT. In discourse interpretation, there is a preference for resolving bridging anaphora in a way that maximizes discourse coherence.

To see more formally how bridging inferences a drawn in SDRT, we will concentrate on the meaning representation of definite descriptions triggering bridging inferences. In Russellian tradition, the denotation of a definite noun phrase can only be given if it fulfills the conditions on existence and uniqueness. This can be written in a short form using the iota operator ι which maps a set containing only one element to this element. An expression $\iota x.P(x)$ representing the core meaning of "the P" denotes x if $\exists x.P(x) \wedge \forall x'[P(x') \rightarrow x' = x]$ is true, if not, it is not defined. Chierchia (1995, p. 221) extends this notion and includes a contextual parameter B for a bridging relation. He claims that "the P" denotes a P that is related by B to an antecedent a to be specified by context. B restricts the domain and must be included in the uniqueness condition. Building on that, Asher and Lascarides (1998a, p. 87) characterize the meaning of a definite noun phrase as $\lambda Q.Q(\iota x(B(x,a) \wedge P(x)))$. This expression applies a predicate Q (the verb meaning) to the entity x, for which P (the meaning of

the NP) is true and that is related by a bridging relation B to some contextually given antecedent a. This meaning characterization corresponds to the SDRT representation shown in (3). Note that the condition of uniqueness is now represented by the DRS condition consisting of the two small DRSs connected by $\Rightarrow$. The representation of an indefinite noun phrase would be very similar, in that we just leave out the uniqueness condition and keep the rest of the conditions.

(3) λQ
$$\frac{u, v, R}{u : \dfrac{e, x, a, B}{Q(k,e), knife(x), B(a,x), B =?, a =? \quad \dfrac{x'}{knife(x') \; B(a,x')} \Rightarrow \boxed{x' = x}} \qquad R(u,v), R =?, v =?}$$

There are two underspecifications to be resolved by pragmatic inference: First, a coherence relation $R(u, v)$ has to be established. According to Asher and Lascarides (1998b), a definite description triggers a coherence relation between the current utterance u and some previous utterance v. Secondly, in the bridging relation $B(a, x)$, the parameters B and a have to be specified (Asher and Lascarides, 1998a). For direct anaphora, B is *identity*. For indirect reference by association, B can be *part-of* or *member-of*. For indirect reference by characterization, B is a thematic role, e.g. *agent*, *theme*, or *instrument*. The question we want to go further into is what kind of information can we exploit to help us drawing these inferences.

3 Frame Semantics

To get clues for the resolution of this kind of bridging inferences, we propose to exploit an idea already mentioned in Gardent *et al.* (2003), but there not pursued further. The idea is to use Frame Semantics developed by Fillmore (1976) and subsequent work on FrameNet (Baker *et al.*, 1998; Fillmore *et al.*, 2003). This framework is based on the central assumption that world knowledge is organized in frames. Basic units are frames and lexical units. Frames are mental representations of stereotypical situations whose elements can only be defined relating one to another. A lexical unit is a pairing of a word with a meaning; polysemous words are represented by several lexical units. Every lexical unit **evokes** a particular frame and can only be understood in relation to that frame.

With each eventuality introduced in the discourse, a corresponding frame is evoked in the discourse model. In this frame, all relevant (necessary or optional) participants of an event are stored. For all core frame elements corresponding to thematic roles, there is a representation in the discourse model, i.e. in the SDRS. In case that some participant is not expressed linguistically, its representation remains underspecified. These roles can be further specified by subsequent information provided that the discourse referent for the eventuality remains accessible for anaphoric reference.

FrameNet (Baker *et al.*, 1998) is a lexical resource providing a body of annotated sentences based on frame semantics. The database contains around 10,000 lexical units, 800 semantic frames and over 120,000 example sentences. Frames are hierarchically organized: e.g. the frame *Killing* inherits the properties from the more general frame *Transitive_action* which in turn inherits from the abstract frame *Event*. A frame consists of various **Frame Elements**, kinds of entities that can participate in a frame. They are defined relative to a frame, and correspond roughly to thematic roles in an event. Sometimes, conceptually necessary Frame Elements don't show up in a sentence. This is the case with omitted agents in passive sentences (Constructional Null Instantiation, CNI), missing obligatory elements that can be inferred from context (Definite Null Instantiation, DNI), or implicit arguments of certain transitive verbs that are used intransitively, e.g. verbs as *eat*, *bake* (Indefinite Null Instantiation, INI). For illustration, the *Killing* frame is described below in Fig. 1, and one of the lexical units evoking that frame, the verb *murder*, is characterized in Fig. 2.[2]

[2]Definitions are taken from the FrameNet Database, obtainable from the International Computer Science Institute, Berkeley, California (http://framenet.icsi.berkeley.edu/).

Definition: A Killer or Cause causes the death of the Victim.

Core Frame Elements :

FE	description	inherited FE	semantic type
Killer	The person or sentient entity that causes the death of the Victim	Agent	sentient
Victim	The living entity that dies as a result of the killing	Patient	sentient
Instrument	The device used by the Killer to bring about the death of the Victim	Instrument	physical entity
Cause	An inanimate entity or process that causes the death of the Victim	Cause	
Means	The method or action that the Killer or Cause performs resulting in the death of the Victim	Means	state of affairs

Non-Core Frame Elements: Beneficiary, Manner, Place, Purpose, Time, ...

Lexical Units: annihilate.v, annihilation.n, ..., murder.n, murder.v, murderer.n, ..., terminate.v

Figure 1: The *Killing* frame

murder.v : Frame elements and valence patterns

frame element	realized as			
Killer	NP.Ext	NP.Ext	PP[by].Dep	CNI.–
Victim	NP.Obj	INI.–	NP.Ext	NP.Ext
(23)	(14)	(1)	(5)	(3)

Figure 2: Lexical entry *murder.v*

As can be seen in Fig. 2, among the 23 annotated sentences in the FrameNet database containing the lexical unit *murder.v*, there are three cases in which the *Killer* was not expressed at all (CNI), and the *Victim* showed up as external argument of the verb. This configuration is typical for passive sentences like (1).

An important question is whether a linguistic expression denoting an eventuality, e.g. a verb, evokes at most one frame, exactly one frame, or more than one frame. As said above, in FrameNet, a *lexical unit* is defined as a pairing of a word with a sense. For a polysemous word, "the separate senses of the word correspond to the different (sets of) frames that the word can participate in. When a word's sense is based on a particular frame, the word evokes the frame" (Fillmore *et al.*, 2003). For example, the verb "break" can evoke, among others, the frame *Experience_bodily_harm* (e.g. in "I broke my leg") or the frame *Render_nonfunctional* (in "I guess I broke the doorknob"). Thus, interpretation of a text requires assumptions about which frame is relevant in the given context. Take the verb "eat": it could be associated with a set of frames, e.g. a restaurant frame, a family home frame, a wild-animals-in-the-open frame, etc. The question is how the right frame ends up being selected. We would suggest to choose the most general frame fitting in the given context. For "eating" this would be the frame *Ingestion*. Due to the hierarchical structure of FrameNet, any frame involving eating would inherit the properties and frame elements of this frame. Of course, if there are very divergent senses of a word, the selected frame perhaps would be too general to be helpful for our purposes. But still, in many cases FrameNet provides very useful information for discourse interpretation.

4 Integrating FrameNet and SDRT

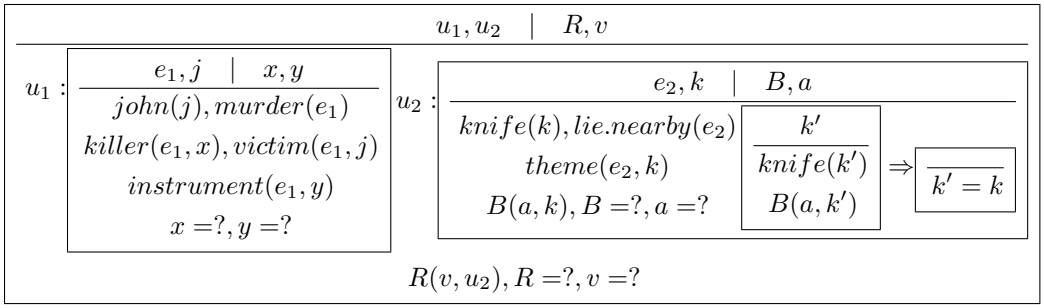
Each eventuality introduced in a discourse evokes a corresponding frame in the discourse model. Its frame elements correspond to all relevant (necessary or optional) thematic roles of the event. We

propose to include for all core frame elements a representation in the discourse model, i.e. in the SDRS of the current utterance. For expository purposes, we will not include non-core frame elements, but surely the discourse model must contain also representations of spatial and temporal coordinates.

In case that some participant of a frame is not expressed linguistically, its representation remains underspecified. These elements can be further specified by subsequent information provided that the discourse referent for the eventuality remains accessible for anaphoric reference. How this can work, we will spell out in more detail in section 5. Before, we will discuss how frame elements can be represented in SDRT, and how they help to determine discourse relations.

In order to integrate FrameNet data in SDRT, we will adopt a Neo-Davidsonian style of event semantics (Parsons, 1990), assuming that lexical units expressing eventualities include an implicit event argument in their semantic representation. Prepared in this way, we can express the underspecified semantic content of (1) as shown in (4).

(4)



According to FrameNet data, in course of interpreting the utterance, the *Killing* frame is evoked by the verb "murder". Its core frame elements[3] show up in the SDRS as $killer(e_1, x)$, $victim(e_1, j)$ and $instrument(e_1, y)$. Similarly, the verb "lie" (in its sense "lie nearby") evokes the frame *Being_located*, with only one core frame element $theme(e_2, k)$.

Thanks to the hierarchical structure of the FrameNet database, the *Killing* frame inherits the properties of the more general abstract frame *Transitive_action* which in turn inherits from *Event*. The frame *Being_located* inherits the frame elements of the abstract frame *State*. As assumed in Asher and Lascarides (2003), the occurrence of an event followed by a state is a strong indicator for the presence of a *Background* relation between the discourse segments containing the eventualities. This can be expressed by a default rule (5)[4] (cf. Asher and Lascarides, 2003, p. 207, Vieu and Prévot, 2004, p. 486). Thus, in example (1), a *Background* relation R between u_1 and u_2 can be assumed.

(5) $u_1 : event(e_1) \wedge u_2 : state(e_2) > Background(u_1, u_2)$

5 Resolving Bridging References

5.1 Constraints on Anaphoric Reference

Resolving bridging anaphora requires two problems to be solved: (i) the correct antecedent to which the anaphor is to be connected has to be found, and (ii) the nature of the bridging relation itself must be identified. For solving (i), possible antecedents must be identified, and impossible ones must be ruled out. For solving (ii), it is helpful to restrict possible relations to conditions on discourse referents already present in the discourse model.

Accessibility for anaphoric reference is constrained by general discourse principles such as the Right Frontier Constraint (RFC, Polanyi, 1988; Webber, 1988). Basically, this constraint draws a distinction between coordinating and subordinating discourse relations: a coordinating relation pushes the right frontier to the right, closing off its attachment point, and a subordinating relation extends the right frontier downwards, leaving open its attachment point. In SDRT, an antecedent for an anaphoric

[3] The core frame elements 'Cause' and 'Means' will be ignored in this paper for the sake of clearness of the exposition, but could be integrated easily. However, they don't add to the main points we want to make in this paper.

[4] '$>$' is a nonmonotonic conditional operator. $A > B$ means: *if A then normally B*.

expression must be DRS-accessible on the right frontier (Asher and Lascarides, 2003). In this way we can refine Asher & Lascarides' meta-rule "discourse structure determines bridging" (see section 2.2).

Recent work in SDRT (Vieu and Prévot, 2004) has revealed that *Background* should be considered as subordinating by default. Accordingly, in (1), u_1 lies on the right frontier of the discourse, and e_1 is accessible for anaphoric reference in u_2. So the discourse structure tells us that, in principle, a bridging relation can be established. Now the question remains how to build the bridge between the knife and the killing event. As seen in the last section, FrameNet data can give important clues to establish discourse relations. But this knowledge is not always sufficient to resolve bridging references. In (1), the presence of a *Background* relation alone is not enough to motivate the bridge. What more information can we get from FrameNet?

The frame element *instrument* in the killing frame must have a semantic type (in the FrameNet sense) "physical_entity". It can be a weapon, but in principle any other physical entity could be used for killing, e.g. hands (6) or a lamp (7).

(6) John killed Mary. He strangled her.

(7) John killed Mary. He stunned her with a lamp.

At the other hand, the lexical unit "knife" evokes the frame *Weapon* with the semantic type "artifact", indicating the possibility that it could serve as an instrument in a killing event. But, as noted in the informal FrameNet description, knives are not necessarily designed as weapons. So this knowledge, at least in the present state of FrameNet, doesn't help us much to resolve the bridging relation. The only knowledge we can use is that there is no clash of semantic types: both knives and killing instruments are physical entities. As far as that we can capture the intuition behind Asher & Lascarides' meta-rule that "bridges must be plausible". It is little more than saying that interpretations must be consistent. In fact, as Zeevat (2006) suggests, selecting the most plausible interpretation given the context and the utterance entails a preference for consistent over inconsistent interpretations. Thus, using FrameNet data, we get at least partly an approximation to the plausibility constraint, which, nevertheless, is a probabilistic notion while consistency is either fulfilled or not.

Looking again at the four meta-rules, there is the first rule "if possible use identity". This rule seems to be subsumed by a very general constraint in discourse interpretation, sometimes called DOAP "Don't overlook anaphoric possibilities" (Williams, 1997). This principle is essentially saying that if there is an anaphoric trigger, we must try to find an antecedent. This preference can be captured by a general low ranked default saying that, unless otherwise indicated, (semantically compatible) discourse referents can be assumed to be equal. Formal details on how *Equality by Default* constrains anaphoric reference are described in Cohen (2007).

As noted above, with the presence of a discourse relation between u_1 and u_2, the discourse referents in u_1 are accessible for anaphoric reference in u_2. So, with Equality by Default, we can assume that a is equal to e_1. Thus, the bridging relation $B(a, k)$ can be specified as $instr(e_1, k)$. As a byproduct, the underspecified variable y in the condition $instr(e_1, y)$ in u_1 can be resolved to k, yielding that instrument and knife refer to the same entity[5]. Note that these inferences are defeasible and can be overridden by subsequent information. Nethertheless, if the bridging relation can be resolved, the discourse turns out to be more coherent. This captures the intuition behind Asher & Lascarides' forth meta-rule "maximize discourse coherence" (MDC). Now consider discourse (8).

(8) a. John was murdered yesterday. b. # The book lay nearby.

This discourse is - in a neutral context - less coherent than (1), and we want to explain why. In example (1), the knowledge that a knife is a kind of weapon that can serve as an instrument in a killing event licenses the bridging inference. In example (8), such a connection cannot be found. Again, a *Background* relation can be inferred, but the role "the book" could play in the killing event is less clear than that of a knife. Although there is no clear semantic connection between "the book" and

[5]Although k is not accessible in u_1, it is accessible in the superordinated SDRS compromising both utterances, and therefore, after processing the second utterance, the underspecification can be resolved.

any evoked core frame element, there is no clash of semantic types, and a bridging relation to the instrument could be plausible. Nethertheless, as no sense of "book" evokes a frame similar to *Weapon*, it remains unclear what nature the bridging relation has, and the discourse seems less coherent. Note again, if the context provides additional evidence that the book is a probable killing instrument, e.g. by being contaminated with poison, the bridging inference indeed can be drawn. To summarize the principles we need for bridging resolution, we remain with the following constraints on anaphoric reference:

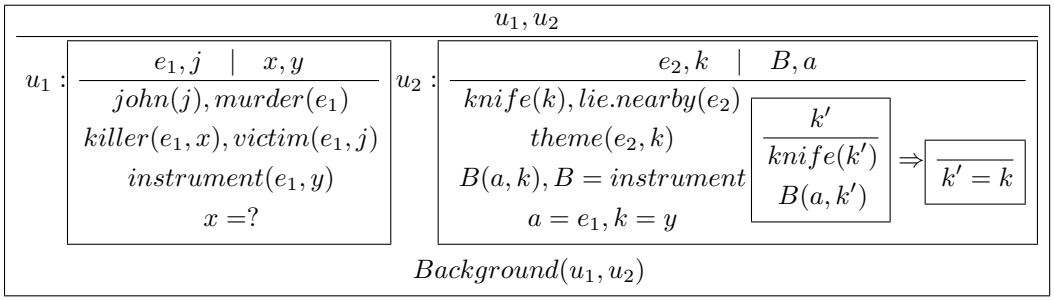
- DOAP
- PLAUSIBLE or CONSISTENT
- RFC
- MDC

Note that they are not meant to be special meta-rules designed for bridging resolution, rather they seem to be more general constraints to be obeyed in discourse interpretation. They could be seen as constraints in optimality theoretic pragmatics, but we won't adopt a particular framework here, as we leave open the question if the ranking of these constraints should be left as stated above. For a related discussion, see Zeevat (2006).

5.2 Weak Discourse Referents

For illustration, a pragmatically enriched SDRS for discourse (1) is shown in (9). Note that, as the murderer is not mentioned at all, his referent could not be resolved and its representation remains underspecified.

(9)



As suggested by the SDRS representations, we now have to deal with two different kinds of discourse entities: 'regular' discourse referents introduced by linguistic expressions, and 'weak' discourse referents which are not (yet) expressed linguistically[6]. *Weak Discourse Referents* are abstract entities which are evoked or activated in course of the interpretation process. A linguistic expression does not introduce them directly, rather indirectly by virtue of the frame a lexical unit evokes. They often remain underspecified, but can be specified by subsequent anaphoric reference. This is what happens with the killing instrument. Its identification with the knife helps to render the discourse more coherent. If the knife in the second sentence had nothing to to with the first sentence, the discourse would be rather incoherent, at least after the utterance of the second sentence.

Our proposal ist to restrict the search space for suitable antecedents for bridging anaphora to take into account only accessible 'regular' and 'weak' discourse referents. In this way, the resolution of bridging inferences can be constrained considerably. In particular, if the principle DOAP applied unrestrictedly, we would never be able to introduce new entities in a discourse. Moreover, it would

[6]A different solution is proposed by Koenig and Mauner (1999). As these authors argue and affirm by experimental evidence, implicit arguments in short passive sentences (a-definites in their terminology) cannot serve as antecedents of definite pronouns. They claim that implicit arguments do not introduce any discourse referent at all. Their DRT representation for the utterance 'A ship was sunk.' is $[y|ship(y), sink(x, y)]$. The problem with this approach is that it is not clear how the free variable x, representing the actor, is interpreted. Moreover, as noted in that paper, bridging references to implicit arguments *are* indeed possible, but no details are given how such an inference is drawn.

take a lot of processing costs to search the entire discourse context for possible antecedents, something very unlikely to be part of human language understanding. In our model, new entities are (weakly) introduced with every eventuality that is talked about, with the potential to be strengthened, to remain in background or even to be dropped.

6 Conclusion

We have extended SDRT's account of bridging to cover reference to eventualities. We have spelled out how world knowledge (represented in frames) contributes to the interpretation process, both for establishing discourse relations and for resolving indirect anaphora. In addition, we could indicate that the meta-principles of Asher and Lascarides (1998a) can be put down to more general constraints to be obeyed in discourse interpretation.

We made an explicit distinction between two types of discourse referents. A further step might be, instead of distinguishing just kinds of referents, to give all discourse referents finer-grained weights on a scale. These numbers could be assigned according to the salience of the referents. Possibly the ranking of forward-looking centers of Centering Theory Grosz *et al.* (1995) might be used to give an ordering of discourse referents in a SDRS. We leave this point to further investigation.

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