1 Introduction

- natural language discourses are structured: relations between utterances at various levels
- basic distinction between coherence and cohesion
  - coherence: text segments are connected by discourse relations
  - cohesion: anaphoric relations in one utterance and spanning even bigger distances

2 Bridging Anaphora

- in a bridging anaphor, an entity introduced in a discourse stands in a particular relation to some previously mentioned discourse entity
- the Bridging Relation (Clark, 1977)
  - is not explicitly stated
  - is an essential part of the discourse content: the knowledge of this relation is needed for successfully interpreting a discourse

2.1 Types of Bridging Anaphora

Clark (1977) distinguishes between direct reference and indirect reference

**direct reference**: the antecedent is an entity just mentioned, as in (1).

(1) I met a man yesterday. He told me a story.

**indirect references by association**: the antecedent is not directly mentioned, but closely associated with an entity mentioned before

- the associated pieces of information vary in their predictability
  - necessary parts
    - (2) I looked into the room. The ceiling was very high.
  - probable parts
    - (3) I walked into the room. The windows looked out to the bay.
  - inducible parts
    - (4) I walked into the room. The chandeliers sparkled brightly.

**indirect reference by characterization**: the bridging relation characterizes a role that something implicitly plays in an event or circumstance mentioned before

- roles can be agents, objects, or instruments
  - necessary roles
    - (5) John was murdered yesterday. The murderer got away.
  - optional roles
    - (6) John was murdered yesterday. The knife lay nearby.

2.2 Expressions Triggering Bridging Inferences

- definite noun phrases
- indefinite noun phrases

2.2.1 Definite Noun Phrases

- most classifications of bridging anaphora start from the observation that bridging relations are triggered mainly by definite descriptions
- Russell (1905): definite descriptions are characterized by two properties: uniqueness and existence.
Uniqueness (Russell, 1905; Kadmon, 1990; Roberts, 2003)
- the referent denoted by the definite description must be the only referent that satisfies
  the given description
- always relative to some restricted context, e.g. a quantification domain or the dis-
  course domain

Familiarity (Heim, 1982; Prince, 1981)
- the referent denoted by the definite description must be known to the hearer
- subsumes Russell’s condition of the existence of a referent
- Prince (1981): familiarity hierarchy
  - discourse-old
  - hearer-old
  - discourse-new
  - hearer-new

Empirical investigations about the use of definite descriptions (cf.Roberts (2003))
- Fraurud (1990): classification definite descriptions based on Swedish corpus data
  - first mention (without NP antecedent): 61 %
  - subsequent mention (with NP antecedent): 39 %
- Poesio and Vieira (1998): classification based on native-speaker annotations (in a prede-
  fined classification scheme) of a corpus of English newspaper articles

<table>
<thead>
<tr>
<th>Class</th>
<th>Poesio &amp; Vieira Occurrences</th>
<th>Prince</th>
<th>Roberts</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>coreferential NPs 43-45 %</td>
<td>discourse-old</td>
<td>strongly familiar</td>
</tr>
<tr>
<td>II</td>
<td>bridging 6-11 %</td>
<td>discourse new, but related to a discourse-old entity</td>
<td>weakly familiar</td>
</tr>
<tr>
<td>III</td>
<td>larger situation 20-25 %</td>
<td>discourse new and hearer-old</td>
<td>&quot;</td>
</tr>
<tr>
<td>IV</td>
<td>unfamiliar 18-26 %</td>
<td>discourse-new and hearer-new and not related to any discourse-old entity</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

- distinction of 3 groups of definite description uses
  1. anaphoric binding
    (7) Ein Affe schläft. Der Affe träumt.
  2. bridging
    (8) Ein Affe träumt. Der Schwanz wackelt.
  3. accomodation
    (10) Ein Affe frisst die Banane.
- preference on resolving DDs (Boe et al., 1995; Gardent and Konrad, 2000):
  - binding > bridging > accommodation
- Gardent et al. (2003): corpus investigation and classifications
  - annotation of DDs

<table>
<thead>
<tr>
<th>Relation</th>
<th>Number</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coreferential</td>
<td>1481</td>
<td>16.85%</td>
</tr>
<tr>
<td>Bridging</td>
<td>416</td>
<td>4.73%</td>
</tr>
<tr>
<td>First mention</td>
<td>6892</td>
<td>78.40%</td>
</tr>
</tbody>
</table>

2.2.2 Indefinite Noun Phrases
- there are also cases of referring indefinite noun phrases which convey a bridging relation
  (10) John was murdered yesterday. A knife lay nearby.
  - "a knife" clearly refers to the probable instrument of murdering, almost identically as in example (11)
  - we will concentrate on utterances involving definites, indicating different behaviour of indefinites whenever necessary

2.3 Bridges between Events
(11) a. John was murdered yesterday.
  b. The knife lay nearby.
  - Utterance (11a)
  - 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 (11b)
describes a state of the entity denoted by the definite noun phrase "the knife"
this entity is new in the discourse, but stands in an implicit relation to the event
described in utterance (11a): the knife served probably as the instrument of the
killing event

The need for pragmatic inference

- the bridging relation is not expressed by linguistic means
- instead, the hearer has to infer it using contextual knowledge
- successful interpretation of (11b) requires some world knowledge:
  - in a murdering event, there must be a victim and a killer
  - normally there is also an instrument used for performing the act
  - a knife can serve as a killing instrument
- only by means of this additional knowledge, the hearer can successfully interpret the
utterance and connect it to the preceding discourse

3 Representing Bridging Anaphora in a Discourse Model

3.1 The Discourse Model

- in a successful interpretation, all information, not only directly expressed but also indi-
rectly inferred, will be part of the discourse model constructed by the hearer in course of
interpretation
- interpretation involves constructing incrementally a structured mental representation of
the discourse
- Cornish (1999): the discourse model 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 theories of discourse structure make use of a notion of discourse relations (or
rhetorical relations or coherence relations), e.g. the frameworks proposed by Polanyi
and RST (Mann and Thompson, 1988)

3.2 Discourse Referents

- Karttunen (1976): conceptual entities which represent persons or things in the world
- the speaker can assume that the (real) entities are known to the hearer
- the entities can be referred to later in a discourse by means of anaphoric relations (e.g.
pronouns or definite NPs)
- discourse referents stand not only for really existing entities, but also for
  - other entities localizable in space and time such as situations or eventualities (i.e.
events, states, processes and actions),
  - concepts or intentionally existing entities like ‘unicorn’ or ‘Santa Claus’, abstract
entities like entity types or kinds, types of eventualities, facts, circumstances ...

- ways of introducing discourse referents into the discourse model (after Cornish, 1999)
  1. by explicit linguistic means: presentational or existential constructions
     - indefinite NPs
     - proper names
     - demonstratives
     - definite NPs
  2. by extralinguistic means
     - gestures with or without linguistic expressions from 1
     - other kinds of indexical devices (Pierce’s notion of index)
  3. implicitly
     - by inferences that can be drawn from a situation or from other discourse refer-
ents
     - ‘life span’ of DRs (Karttunen, 1976): discourse segment in which an introduced DR can
       be accessed
     - distinction of permanent and temporary DRs
     - permanent DRs
       - are introduced in referentially transparent contexts
     (12) Bill saw a unicorn. The unicorn had a golden mane.
     - temporary (‘short-term’) DRs
       - are introduced in referentially opaque contexts which are created by modal operators
         (e.g. negation, world-creating verbs, contrafactual constructions, certain quantifiers)
       - the life-span of DRs is restricted to the duration of the referentially opaque context
         (e.g. the scope of a modal operator)
     (13) Bill didn’t see a unicorn. The unicorn had a golden mane.
       - nevertheless, the opaque contexts can be extended later by modally equivalent op-
erators in later utterances, making subsequent anaphoric reference possible
     (14) Bill didn’t see a unicorn. If he had, it would certainly have a golden
mane.

Accessibility

- accessibility and salience of discourse referents
- Gundel et al. (1993): Givenness Hierarchy
  in uniquely type
  focus < activated < familiar < identifiable < referential < identifiable
  this/that/this N that N the N indefinite this N a N
  - “in focus”: anaphoric reference via pronouns (it) allowed
  - “activated”: more complex anaphoric expressions must be used (that oder this oder
this N), etc.
3.3 Bridging in SDRT

Segmented Discourse Representation Theory

- dynamic semantics (DRT, Kamp and Reyle, 1993) + two new expressions
  1. **speech act discourse referents** which label content of text segments and keep track of token utterances
  2. **rhetorical relations** which relate speech act discourse referents
- the resulting structures are segmented DRSs (SDRSs)

Bridging as byproduct of computing discourse structure

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

Meaning representation of definite descriptions triggering bridging inferences

- Russell (1905): the denotation of a definite noun phrase can only be given if it fulfills the conditions on existence and uniqueness
- notation: iota operator \( \iota \) 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 \( \exists x.P(x) \land \forall x'(P(x') \rightarrow x' = x) \) is true, if not, it is not defined
- Chierchia (1995, p. 221) includes a contextual parameter \( B \) for a bridging relation
- “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
- Asher and Lascarides (1998a, p. 87) characterize the meaning of a definite noun phrase as

\[
\lambda Q. Q(x(x(B(x,a) \land P(x))))
\]
**FrameNet** (Baker *et al.*, 1998)

- 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 **Transitive_action**, which inherits from **Event**
- A frame consists of various **Frame Elements**; kinds of entities that can participate in a frame

**Frame Elements**

- 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:
  - **Constructional Null Instantiation, CNI**: omitted agents in passive sentences (e.g. *The ship was sunk.*)
  - **Definite Null Instantiation, DNI** (also *anaphoric implicit FEs*): missing obligatory elements inferable from linguistic or situational context (e.g. the utterance *I object!* need speaker and hearer to be aware of the proposition currently being opposed)
  - **Indefinite Null Instantiation, INI** (also *existential implicit FEs*): implicit arguments of certain transitive verbs that are used intransitively (e.g. verbs as *eat*, *bake*)
- The **Killing** frame

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

**Core Frame Elements**:

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

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

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

---

1Definitions are taken from the FrameNet Database, obtainable from the International Computer Science Institute, Berkeley, California (http://framenet.icsi.berkeley.edu/).
• 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

Anaphora and Discourse Structure

4.3 Representing Frames in SDRT
• Neo-Davidsonian style of event semantics (Parsons, 1990)
  - lexical units expressing eventualities include an implicit event argument in their semantic representation
  - thematic roles in an event are represented as conditions in form of predicates whose first argument is this event argument
  - semantic representation of the sentence “John eats an apple.”: \( \exists e \exists y \exists a[\text{eat}(e) \land \text{agent}(e, a) \land \text{theme}(e, a) \land \text{john}(j) \land \text{apple}(a)] \)

(17) a. John was murdered yesterday.
   b. The knife lay nearby.

(18)

\[
\begin{align*}
R_{2} & \quad | \quad R_{1} \\
\text{coherence} & \quad | \quad \text{coherence} \\
\text{cohesion} & \quad | \quad \text{cohesion} \\
\text{direct anaphoric} & \quad | \quad \text{direct anaphoric} \\
\text{bridging} & \quad | \quad \text{bridging} \\
\end{align*}
\]

4.4 Establishing Discourse Relations by FrameNet Data
• the FrameNet database is hierarchically structured
  - the Killing frame inherits the properties of Transitive action which in turn inherits from Event
  - the frame Being located inherits the frame elements of the abstract frame State
• Asher and Lascarides (2003): the occurrence of an event followed by a state is a strong indicator for the presence of a Background relation
• this can be expressed by a default rule (19)\(^3\) (cf. Asher and Lascarides, 2003, p. 207, Vieu and Prévot, 2004, p. 486)

(19) \( u_{1} : \text{event}(e_{1}) \land u_{2} : \text{state}(e_{2}) > \text{Background}(u_{1}, u_{2}) \)
• in example (11), a Background relation \( R \) between \( u_{1} \) and \( u_{2} \) can be assumed

5 Resolving Bridging References
5.1 Constraints on Anaphoric Reference
• resolving bridging anaphora requires two problems to be solved:
  1. the correct antecedent to which the anaphor is to be connected has to be found
     - possible antecedents must be identified
     - impossible antecedents must be ruled out
  2. the nature of the bridging relation itself must be identified
     - restrict possible relations to conditions on discourse referents already present in the discourse model
• accessibility for anaphoric reference is constrained by general discourse principles

The Right Frontier Constraint (RFC, Polanyi, 1988; Webber, 1988)
• distinction between coordinating and subordinating discourse relations:
  - a coordinating relation pushes the right frontier to the right, closing off its attachment point
  - a subordinating relation extends the right frontier downwards, leaving open its attachment point
• in SDRT, an antecedent for an anaphoric 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”

\(^3\)The core frame elements ‘Cause’ and ‘Means’ will be ignored for the sake of cleanness of the exposition, but could be integrated easily. However, they don’t add to the main points we want to make here.

\(^4\) ‘\( \triangleright \)’ is a nonmonotonic conditional operator: \( A \triangleright B \) means if \( A \) then normally \( B \).
(Vieu and Prévot, 2004): Background should be considered as subordinating by default
in (11), \(u_1\) lies on the right frontier of the discourse, and \(e_1\) is accessible for anaphoric reference in \(u_2\)
the discourse structure says that, in principle, a bridging relation can be established
in (11), the presence of a Background relation alone is not enough to motivate the bridge
What more information can we get from FrameNet to build the bridge between the knife and the killing event?
The Plausibility Constraint
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 (20) or a lamp (21)
(20) John killed Mary. He strangled her.
(21) John killed Mary. He strangled her with a lamp.
the lexical unit “knife” evokes the frame Weapon with the semantic type “artifact”: 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
this knowledge 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”
little more than saying that interpretations must be consistent
Zeewat (2006): selecting the most plausible interpretation given the context and the utterance entails a preference for consistent over inconsistent interpretations
→ using FrameNet data, we get at least partly an approximation to the plausibility constraint
Equality by Default
Asher & Lascarides’ first meta-rule “if possible use identity” seems to be subsumed by a very general constraint in discourse interpretation
Williams (1997): DOAP “Don’t overlook anaphoric possibilities”: if there is an anaphoric trigger, we must try to find an antecedent
can be captured by a “Equality by Default” (Cohen, 2007): a general low ranked default saying that, unless otherwise indicated, (semantically compatible) discourse referents can be assumed to be equal
Maximize Discourse Coherence
5.2 Weak Discourse Referents

- pragmatically enriched SDRS for discourse (11):

\[\begin{align*}
&\text{Background}(u_1, u_2) \\
&\begin{array}{|c|c|}
\hline
u_1 & u_2 \\
\hline
x, y & x = ? \\
\hline
\end{array}
\end{align*}\]

\[\begin{align*}
&\text{killer} (e_1, x), \text{victim} (e_1, j), \text{instrument} (e_1, y) \\
&\text{knife} (k), \text{lie.nearby} (e_2) \quad \text{theme} (e_2, k) \\
&\text{B} (a, k), \text{B} = \text{instrument}, a = e_1, k = y \\
&\text{k}’ = \text{k}
\end{align*}\]

- we now have to deal with two different kinds of discourse entities:
  - 'regular' discourse referents introduced by linguistic expressions
  - 'weak' discourse referents which are not (yet) expressed linguistically

Weak Discourse Referents

- 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
- in (11):
  - the identification of the killing instrument with the knife helps to render the discourse more coherent
  - if the knife in the second sentence had nothing to do with the first sentence, the discourse would be rather incoherent, at least after the utterance of the second sentence
- proposal: restrict the search space for suitable antecedents for bridging anaphora to take into account only accessible 'regular' and 'weak' discourse referents
- the resolution of bridging inferences can be constrained considerably
- if the principle DOAP applied unrestrictedly, we would never be able to introduce new entities in a discourse
- it would 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
- 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 Related Approaches

6.1 Implicit Arguments as A-definites (Koenig and Mauner, 1999)

(24) a. A ship was sunk
    b. A ship sank
    c. A ship was sunk by someone
    d. ... to collect settlement money from the insurance company.

- verbs like sunk in (a) include an implicit actor argument as part of the representation of lexical items
- in (d), readers must anchor the anaphoric PRO subject of collect
- psycholinguistic evidence (Mauner et al., 1995): subjects take longer to process rationale clauses like (d) when they follow intransitive sentences like (b) than when they follow short passives (a) or agentive passives (c)
- distinction between quantificational, indefinite and definite NPs
- nonquantificational NPs or pronominals have (at least) three main distinct functions within DRT (ex. A man smiled. He was happy.):
  1. They can introduce new discourse markers to which subsequent nps can refer back;
  2. They satisfy one of a main predicate’s arguments;
  3. They introduce a restriction on the referent of the discourse marker that they introduce.
- the French subject clitic on, the German man, indefinite uses of English they do not fulfill the first function

(25) a. On a assassiné la présidente.
    b. #Il était du Berry, paraît-il.
      ‘Someone murdered the (woman) president. He, was from the Berry, it seems.’

(26) a. Quelqu’un a assassiné la présidente.
    b. Il était du Berry, paraît-il.
      ‘Someone murdered the (woman) president. He, was from the Berry, it seems.’
I would like to begin a new book tonight.

Problems with this approach

- it is not clear how the free variable $x$, representing the actor, is interpreted
- as noted in their paper, bridging references to implicit arguments are indeed possible

(28) a. Bill hurried to catch his plane.
   b. The suitcases were very heavy.

(29) a. They killed the president.
   b. The terrorists were merciless.

- Koenig and Manner (1999) give no details how such an inference is drawn

6.2 Bridging as Coercive Accommodation (Bos et al., 1995)

- van der Sandt (1992)'s account of accommodation in DRT (Kamp and Reyle, 1993) takes presuppositions to behave like anaphora
  - accommodation

(30) When I give a party, the King of France always attends it.
  - is different from linking

(31) When I invite a celebrity, the celebrity never comes.
  - is different from bridging (Bos et al., 1995)

(32) When I go to a bar, the barkeeper always throws me out.

- definite descriptions that can be bridged to existing information do not need the accommodation of new referents; (30) requires accommodation, but (32) can be solved with mere bridging


Generative Lexicon: Qualia Structure

- qualia structure can be seen as a set of lexical entailments
  - e.g. the word book entails the events of reading and writing and consists of several separate parts, like the cover, pages, etc.
- four qualia roles to represent such knowledge: formal, constitutive, telic, agentive
  - a book is at the same time a physical object and an information container

Generative Lexicon: Coercion

(33) I would like to begin a new book tonight.

- the verb begin expects an event but here there is only an artifact (book)
- metonymic reconstruction: "use the qualia structure of this artifact to infer some event that is entailed by it and which can stand in its place"
- Coercion: "anytime a word or phrase is not of the desired type (or sort) (like artifact, event, etc.) we are allowed to coerce it into one of its entailments that is of the appropriate type, where the entailments are stored in its qualia structure"
• resolved DRS

\[
\begin{array}{c|c|c|c}
| x, y & \text{bar}(x) & \text{barkeeper}(y) & Q \\
\hline
I - go - to(x) & always - throws - me - out(y) & y = z
\end{array}
\]

Problems with this approach
Limitation to certain kinds of definite descriptions
• Bos et al. (1995) cite the following example as a limitation case of their approach

(35) Probably, if Jane takes a bath, Bill will be annoyed that there is no more hot water.

• the inference is made that taking a bath involves using a hot water reservoir
• in FrameNet, the lexical unit take a bath\(^4\) evokes the frame Cause_to_be_wet with a core frame element liquid, thus allowing the needed inference to be drawn

Treatment of bridging as lexical phenomenon
• as Piwek and Krahmer (2000) note, not all implied antecedents are lexical entailments; sometimes non-lexical background knowledge is needed; their example:

(36) Yesterday, Chomsky analyzed a sentence on the blackboard, but I couldn’t see the tree.

7 Conclusion

we have ...
• ... extended SDRT’s account of Bridging to cover reference to eventualities
• ... spelled out how world knowledge (represented in frames) contributes to the interpretation process
• for establishing discourse relations and - for resolving indirect anaphora
• ... indicated that the meta-principles of Asher and Lascarides (1998a) can be put down to more general constraints to be obeyed in discourse interpretation
• ... made an explicit distinction between two types of discourse referents

a further step:
• instead of distinguishing just two kinds of referents, give all discourse referents finer-grained weights on a scale
• ranking of forward-looking centers of Centering Theory (Groz et al., 1995) might be used to give an ordering of discourse referents in a SDRT

\(4\)The present state of English FrameNet doesn’t include phrasal verbs as lexical units; but in other versions of FrameNet, such knowledge is encoded; an equivalent sentence in Spanish using the verb ‘batharse’ (to take a bath) is analysable in FrameNet terms (see http://gemini.uab.es/)

References