Task Oriented Dialog, Classic Models

Marilyn Walker. CS245. April 1st, 2010
Look at Syllabus

- Need to do sign ups for papers starting next week
- Will finish post May 10th and then another round of sign up.
- Each person probably has to do two papers.
- If a long paper and two short papers are on the same day, its because I think the two short papers are closely enough related to count as one presentation and should be combined.
Dialogue Processing

- Grosz & Sidner 1986
  - Planning, Grice
- Grosz, Joshi & Weinstein 1995
- Sidner 1981
  - Centering, Focusing
- Local and Global discourse structure
- Interaction between them
- Very influential for a time
- Basic assumptions still reflected in current work
Cusp of Empirical Approaches in NLP

- Penn Treebank first available ~ 1990
  - Plenty of data for parsing and POS
  - But what about language behavior above the sentence?
  - What about interactive language?
- 1996: NSF Workshop on Discourse & Dialogue Tagging => DAMSL markup
Grosz and Sidner 1986
Theory of discourse structure

- As opposed to meaning (needs to partially rest on the discourse structure)
- Stresses discourse purpose and processing
- 3 separate but interrelated components (needed to explain interruptions, referring expressions, etc.):
  - Linguistic structure (sequence of utterances)
  - Intentional structure
  - Attentional state
- General view that everyone else was confused
This distinction simplifies both the explanations given + computation mechanism used.

Speaker/hearer ICP/OCP
Linguistic structure

- Utterances in a discourse are naturally aggregated into discourse segments (like words into constituent phrases)

- Segments are not necessarily continuous (interruptions)

- LS is not strictly decompositional

- 2-way interaction between discourse segment structure and utterances constituting the discourse:
  - linguistic expressions can convey info about discourse structure (cue phrases, *ling. boundary markers*)
  - Discourse structure constraints the interpretation of these ling. expressions
Intentional Structure

- Discourse (participants) have an **overall purpose**

- Even though there might be more than one, G&S distinguish one as *foundational to the discourse* (vs. private purposes) which **needs to be recognized**

- Each discourse segment has a **discourse segment purpose (DSP)**, which contributes to the overall DP
Intentional structure cntd.

- 2 structural relationships between DSP:
  - **Dominance**
    DSP1 contributes to DSP2 = DSP2 dominates (DOM) DSP1
  - **Satisfaction-precedence** (Parsing: linear precedence)
    DSP1 satisfaction-precedes DSP2 when 1 must be satisfied before 2

- The dominance relation invokes a partial ordering on DSPs, i.e. a **dominance hierarchy**

- **Determinations** (complete specification of what is intended by whom) vs. **recognition**
  - (contrast with RST and coherence relations)
Attentional State

- As opposed to cognitive state, which is a richer structure that includes knowledge, beliefs, desires and intentions

- Abstraction of the **participants’ focus of attention** as their discourse unfolds (a property of the discourse itself)

- **Dynamic**: records the objects, properties and relations that are salient at each point in the discourse
Attentional State cntd.

- Modeled by a set of **focus spaces** which constitute the focusing structure

- A focus space = segment + DSP

- Although each focus space contains a DSP, the focus structure does not include the intentional structure as a whole

- The **stacking** of focus spaces reflects the salience of entities in each space during the corresponding segments of the discourse
Attentional State cntd.

- Focusing structure depends on the intentional structure: the relationships between DSPs determine pushes and pops from the stack.

- Focusing structure coordinates the linguistic and intentional structures during processing (p. 181).

- Like the other 2 structure, focusing structure evolves as discourse proceeds.
Discourse examples: Task Oriented Dialogue

DS1
(1) E: First you have to remove the flywheel.
(2) A: How do I remove the flywheel?
(3) E: First, loosen the two allen head setscrews holding it to the shaft, then pull it off.
(4) A: OK.

DS2
(5) I can only find one screw. Where's the other one?
(6) E: On the hub of the flywheel.
(7) A: That's the one I found. Where's the other one?
(8) E: About ninety degrees around the hub from the first one.
(9) A: I don't understand. I can only find one. Oh wait, yes I think I was on the wrong wheel.
(10) E: Show me what you are doing.
(11) A: I was on the wrong wheel and I can find them both now.

DS3
(12) The tool I have is awkward. Is there another tool that I could use instead?
(13) E: Show me the tool you are using.
(14) A: OK.
Focus Stack operations driven by intentions

Figure 7. Focus Stack Transitions Leading up to Utterance (25).
Processing issues

- Intention **recognition**
  - **What info** can the OCP use to recognize an intention
  - At **what point** does this info become available

- Overall processing module has to be able to **operate on partial information**

- It must allow for **incrementally constraining the range of possibilities** on the basis of new info that becomes available as the segment progresses
Constraints on the DSP

- Specific linguistic markers, cue words
- Utterance-level intentions (Grice’s maxims)
- General knowledge about actions and objects in the domain of discourse
- Applications:
  - Interruptions (weak vs. strong) (p. 192)
  - Cue words (p. 196)
  - Constraints on anaphora resolution

D2 is an interruption that breaks the flow of D1 and is distinct from D1.

D1: John came by and left the groceries
D2: Stop that you kids
D1: and I put them away after he left

Using the theory described in previous sections, we can capture the above intuitions about the nature of interruptions with two slightly different definitions. The strong definition holds for those interruptions we classify as “true interruptions” and digressions, while the weaker form holds for those that are flashbacks. The two definitions are as follows:

**Strong definition:** An interruption is a discourse segment whose DSP is not dominated nor satisfaction-preceded by the DSP of any preceding segment.
Problems of discourse-level intentions

- DP/DSP are natural extensions of Grice’s utterance-level meanings… but G&S don’t address meaning

- What are the possible intentions

- Empirical work during the 90s on intention based segmentation had trouble getting high reliability on where the segment boundaries were

- G&S state that the modes of correlation that operate at the utterance-level (c) also function at the discourse level
Contrast this view of ‘intentions’ with RST
Intentional structure cntd.

- 2 structural relationships between DSP:
  - **Dominance**
    - DSP1 contributes to DSP2 = DSP2 dominates (DOM) DSP1
  - **Satisfaction-precedence** (Parsing: linear precedence)
    - DSP1 satisfaction-precedes DSP2 when 1 must be satisfied before 2

- The dominance relation invokes a partial ordering on DSPs, i.e. a **dominance hierarchy**

- **Determinations** (complete specification of what is intended by whom) **vs. recognition**

- (contrast with RST and coherence relations)
RST [Mann & Thompson, 1988] associate discourse relations with discourse structure (TEXT).

- Discourse structure reflects context-free rules called schemas.
- Applied to a text, schemas define a tree structure in which:
  - Each leaf is an elementary discourse unit (a continuous text span);
  - Each non-terminal covers a contiguous, non-overlapping text span;
  - The root projects to a complete, non-overlapping cover of the text;
  - Discourse relations (aka rhetorical relations) hold only between daughters of the same non-terminal node.
RST schemas differ with respect to:
- what rhetorical relation, if any, hold between right-hand side (RHS) sisters;
- whether or not the RHS has a head (called a nucleus);
- whether or not the schema has binary, ternary, or arbitrary branching.

RST schema types in RST annotation
Example 1

(a) George Bush supports big business. SATELLITE
(b) He's sure to veto House Bill 1711. NUCLEUS

Relation name: EVIDENCE (MT 1987)

Evidence is a “presentational relation”

Constraints on Nucleus: H might not believe Nucleus to a degree satisfactory to S.
Constraints on Satellite: H believes Satellite or will find it credible.
Constraints on Nucleus + Satellite combination: H's comprehending Satellite increases H's belief of Nucleus.
Effect: H's belief of Nucleus is increased
Example 1

(a) George Bush supports big business.
(b) He's sure to veto House Bill 1711.

Relation name: VOLITIONAL-CAUSE

Volitional Cause is a “subject matter” relation

- Constraints on Nucleus: presents a volitional action or situation that could have arisen from a volitional action.
- Constraints on Satellite: none.
- Constraints on Nucleus + Satellite combination: Satellite presents a situation that could have caused the agent of the volitional action in Nucleus to perform that action; without the presentation of Satellite, H might not regard the action as motivated or know the particular motivation; Nucleus is more central to S's purposes in putting forth the Nucleus-Satellite combination than Satellite is.
- Effect: H recognizes the situation presented in Satellite as a cause for the volitional action presented in Nucleus.
Moore & Pollack 1992

- Presentational relations: == Speaker intention
- Speaker *always* has an INTENTION
- But Informational (subject matter relations) also necessary to understand the discourse

- Multiple levels of analysis are simultaneously available
Studies on Discourse Segmentation

- Large number of studies looking at
  - Cue words
  - Anaphora chains
  - Prosodic markers
  - Reliability of annotation
Global vs. Local Structure
Brennan et al 1987 (my first paper)
Centering

- Centering is formulated as a theory that relates focus of attention, choice of referring expression, and perceived coherence of utterances, within a discourse segment [Grosz et al., 1995].
- Brennan, Walker & Pollard 1987: Centering theory of Anaphora Resolution
Definitions

**Utterance** – A sentence in the context of a discourse.

**Center** – An entity referred to in the discourse (our discourse referents).

**Forward looking centers** – An utterance $U_n$ is assigned a set of centers $C_f(U_n)$ that are referred to in $U_n$ (basically, the drefs introduced / accessed in a sentence).

**Backward looking center** – An utterance $U_n$ is assigned a single center $C_b(U_n)$, which is equal to one of the centers in $C_f(U_{n-1}) \cap C_f(U_n)$. If there is no such center, $C_b(U_n)$ is NIL.
Ranking of forward looking centers

- $C_f(U_n)$ is an ordered set.

- Its order reflects the prominence of the centers in the utterance.

- The ordering (ranking) is done primarily according to the syntactic position of the word in the utterance (subject > object(s) > other).

- The prominent center of an utterance, $C_p(U_n)$, is the highest ranking center in $C_f(U_n)$. 
Ranking of forward looking centers

- Think of the backward looking center $C_b(U_n)$ as the **current topic**.

- Think of the preferred center $C_p(U_n)$ as the **potential new topic**.
Constraints on centering

1. There is precisely one $C_b$.

2. Every element of $C_f(U_n)$ must be realized in $U_n$.

3. $C_b(U_n)$ is the highest-ranked element of $C_f(U_{n-1})$ that is realized in $U_n$. 
An example (Brennan et al. 1987)

- \textbf{U}_1. John drives a Ferrari.
- \textbf{U}_2. He drives too fast.
- \textbf{U}_3. Mike races him often.
Let’s see what the centers are…

- **U₁.** John drives a Ferrari.  
  \[ C_b(U₁) = \text{NIL (or: John)}. \quad C_f(U₁) = (\text{John, Ferrari}) \]

- **U₂.** He drives too fast.  
  \[ C_b(U₂) = \text{John}. \quad C_f(U₂) = (\text{John}) \]

- **U₃.** Mike races him often.  
  \[ C_b(U₃) = \text{John}. \quad C_f(U₃) = (\text{Mike, John}) \]

- **U₄.** He sometimes beats him.  
  \[ C_b(U₄) = \text{Mike}. \quad C_f(U₄) = (\text{Mike, John}) \]
## Types of transitions

<table>
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<th>Transition Type from $U_{n-1}$ to $U_n$</th>
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Let’s see what the transitions are...

- **U₁**: John drives a Ferrari.
  \[ C_b(U_1) = \text{John}. \quad C_f(U_1) = (\text{John}, \text{Ferrari}) \]

- **U₂**: He drives too fast.
  \[ C_b(U_2) = \text{John}. \quad C_f(U_2) = (\text{John}) \]
Let’s see what the transitions are...

- **U₁.** John drives a Ferrari.
  \[C_b(U_1) = \text{John. } C_f(U_1) = (\text{John, Ferrari})\]

- **U₂.** He drives too fast. (continuation)
  \[C_b(U_2) = \text{John. } C_f(U_2) = (\text{John})\]
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- **U₂.** He drives too fast. (continuation)
  \[ C_b(U_2) = \text{John}. \quad C_f(U_2) = (\text{John}) \]

- **U₃.** Mike races him often.
  \[ C_b(U_3) = \text{John}. \quad C_f(U_3) = (\text{Mike, John}) \]
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  $C_b(U_1) = \text{John}$. $C_f(U_1) = (\text{John}, \text{Ferrari})$

- $U_2$. He drives too fast. (continuation)
  $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John})$

- $U_3$. Mike races him often. (retaining)
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  \[C_b(U_1) = \text{John}. \quad C_f(U_1) = (\text{John}, \text{Ferrari})\]

- **U₂.** He drives too fast. *(continuation)*
  \[C_b(U_2) = \text{John}. \quad C_f(U_2) = (\text{John})\]

- **U₃.** Mike races him often. *(retaining)*
  \[C_b(U_3) = \text{John}. \quad C_f(U_3) = (\text{Mike}, \text{John})\]

- **U₄.** He sometimes beats him.
  \[C_b(U_4) = \text{Mike}. \quad C_f(U_4) = (\text{Mike}, \text{John})\]
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Let’s see what the transitions are...

- \( U_1 \). John drives a Ferrari.
  \[ C_b(U_1) = \text{John}. \quad C_f(U_1) = (\text{John}, \text{Ferrari}) \]

- \( U_2 \). He drives too fast. (continuation)
  \[ C_b(U_2) = \text{John}. \quad C_f(U_2) = (\text{John}) \]

- \( U_3 \). Mike races him often. (retaining)
  \[ C_b(U_3) = \text{John}. \quad C_f(U_3) = (\text{Mike}, \text{John}) \]

- \( U_4 \). He sometimes beats him. (shifting-1)
  \[ C_b(U_4) = \text{Mike}. \quad C_f(U_4) = (\text{Mike}, \text{John}) \]
1. If some element of $C_f(U_{n-1})$ is realized as a pronoun in $U_n$, then so is $C_b(U_n)$.

2. Continuation is preferred over retaining, which is preferred over shifting-1, which is preferred over shifting:

   Cont $>>$ Retain $>>$ Shift-1 $>>$ Shift
Cusp of Empirical Approaches in NLP

- Penn Treebank first available ~ 1990
  - Plenty of data for parsing and POS
  - But what about language behavior above the sentence?
  - What about interactive language?
- 1996: NSF Workshop on Discourse & Dialogue Tagging => DAMSL markup
Centering algorithm

- An algorithm for centering and pronoun binding has been developed by Susan E. Brennan, Marilyn W. Friedman (me) and Carl J. Pollard,
- Based on centering theory as specified in:
  - Joshi & Weinstein 1981
  - Grosz Joshi Weinstein 1983 conference paper
  - Draft of GJW 1995 circulating since 1985
  - When I went to Penn I helped Aravind finish it.....
For each utterance perform the following steps

Anchor construction: Create all possible anchors (pairs of forward centers and a backward center).

Anchor filtering: Filter out the bad anchors according to various filters.

Anchor ranking: Rank the remaining anchors according to their transition type.
General structure of algorithm

- First: filtering based on hard constraints
- Then: ranking based on some soft constraints
Construction of the anchors

1. Create a list of referring expressions (REs) in the utterance, ordered by grammatical relation.

2. Expand each RE into a center according to whether it is a pronoun or a proper name. In case of pronouns, the agreement features must match.

3. Create a set of backward centers according to the forward centers of the previous utterance, plus NIL.

4. Create a set of anchors, which is the Cartesian product of the possible backward and forward centers.
Filtering the proposed anchors

- The constructed anchors undergo the following filters.

1. Remove all anchors that assign the same center to two syntactic positions that cannot co-index (binding theory).

2. Remove all anchors which violate constraint 3, i.e. whose $C_b$ is not the highest ranking center of the previous $C_f$ which appears in the anchor's $C_f$ list.

3. Remove all anchors which violate rule 1. If the utterance has pronouns then remove all anchors where the $C_b$ is not realized by a pronoun.
Ranking the anchors

- Classify, every anchor that passed the filters, into its transition type (cont, retain, shift-1, shift).
- Choose the anchor with the most preferable transition type according to rule 2.
Let’s look at an example

- **U₁.** John likes to drive fast.
  \( C_b(U₁) = \text{John}. \ C_f(U₁) = (\text{John}) \)

- **U₂.** He races Mike.
  \( C_b(U₂) = \text{John}. \ C_f(U₂) = (\text{John}, \text{Mike}) \)

- **U₃.** Mike beats him sometimes.

Let’s generate the anchors for **U₃**.
Anchor construction for $U_3$

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John}, \text{Mike})$
- $U_3$. Mike beats him sometimes.

1. Create a list of REs.

REs in $U_3$

Mike  him
Anchor construction for $U_3$

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John, Mike})$
- $U_3$. Mike beats him sometimes.

1. Create a list of REs.
2. Expand into possible forward center lists.
Anchor construction for $U_3$

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John}, \text{Mike})$
- $U_3$. Mike beats him sometimes.

1. Create a list of REs.
2. Expand into possible forward center lists.
3. Create possible backward centers according to $C_f(U_2)$.

### Potential $C_b$s
- John
- Mike
- NIL

### Potential $C_f$s
- Mike
- John

### REs in $U_3$
- Mike
- him
Anchor construction for $U_3$

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John, Mike})$
- $U_3$. Mike beats him sometimes.
  1. Create a list of REs.
  2. Expand into possible forward center lists.
  3. Create possible backward centers according to $C_f(U_2)$.
  4. Create a list of all anchors (cartesian product).
Anchor construction for $U_3$

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John}, \text{Mike})$
- $U_3$. Mike beats him sometimes.

1. Create a list of REs.
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4. Create a list of all anchors (cartesian product).

$$
\begin{array}{cccccccc}
\text{John} & \text{John} & \text{Mike} & \text{Mike} & \text{NIL} & \text{NIL} \\
\text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} \\
\text{John} & \text{Mike} & \text{John} & \text{Mike} & \text{John} & \text{Mike} \\
\end{array}
$$
Filtering the anchors

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John, Mike})$
- $U_3$. Mike beats him sometimes.

1. Remove all anchors that assign the same center to two syntactic positions that cannot co-index.
Filtering the anchors

- \( C_b(U_2) = \text{John} \). \( C_f(U_2) = (\text{John}, \text{Mike}) \)
- \( U_3 \). Mike beats him sometimes.

1. Remove all anchors that assign the same center to two syntactic positions that cannot co-index.

2. Remove all anchors which violate constraint 3, i.e. whose \( C_b \) is not the highest ranking center in \( C_f(U_2) \) which appears in the anchor’s \( C_f \).
Filtering the anchors

- \( C_b(U_2) = \) John. \( C_f(U_2) = (\) John, Mike\( ) \)
- \( U_3 \). Mike beats him sometimes.

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3. Remove all anchors which violate rule 1, i.e. the \( C_b \) must be realized by a pronoun.

\[
\begin{array}{cccccc}
\text{C}_b & \text{John} & \text{John} & \text{Mike} & \text{Mike} & \text{NIL} & \text{NIL} \\
\text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} & \text{Mike} \\
\text{him} & \text{Mike} & \text{John} & \text{Mike} & \text{John} & \text{Mike} \\
\end{array}
\]
Ranking the anchors

- $C_b(U_2) = \text{John}$. $C_f(U_2) = (\text{John}, \text{Mike})$

- The only remaining anchor –
  $C_b(U_3) = \text{John}$. $C_f(U_3) = (\text{Mike}, \text{John})$

- RETAIN
Evaluation

- The algorithm waits until the end of a sentence to resolve references, whereas humans appear to do this on-line.
Centering vs Hobbs


- Walker 1989 manually compared a version of centering to Hobbs on 281 examples from three genres of text.

- Reported 81.8% for Hobbs, 77.6% centering.
Cusp of Empirical Approaches in NLP

- Centering in Italian, Turkish, Korean, Japanese etc.
- Corpus based studies
Corpus-based Evaluation of Centering

Walker 1996: Limited Attention & Discourse Structure
LIMITED ATTENTION CONSTRAINT
Walker 1993, 1996

- ellipsis interpretation
- pronominal anaphora interpretation
- BUT ALSO:
  - Inference of discourse relations between utterances A and B
    - B MOTIVATES A
    - B is EVIDENCE for A
How is attention modeled?

- Linear Recency
- Hierarchical Recency
What about Processing & Centering?

<table>
<thead>
<tr>
<th>Dialogue A</th>
<th>Dialogue B</th>
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<td>(6) C: Hank.</td>
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<td>(7) H: Go ahead Hank</td>
<td>(6.2) H: Is that H A N K?</td>
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<tr>
<td>(8a) C: as well as her uh husband.</td>
<td>(6.3) C: Yes.</td>
</tr>
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<td>(8b) They have a child.</td>
<td></td>
</tr>
<tr>
<td>(8c) and they bring the child to us every day for babysitting.</td>
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Informationally Redundant Utterances

(3) E: And I was wondering – should I continue on with the certificates or
(4) H: Well it’s difficult to tell because we’re so far away from any of them – but I
would suggest this – if all of these are 6 month certificates and I presume they are
(5) E: Yes
(6) H: Then I would like to see you start spreading some of that money around
(7) E: uh huh
(8) H: Now in addition, how old are you?

(discussion and advice about retirement investments)

(21) E: uh huh and
(22a) H: But as far as the certificates are concerned,
(22b) I’D LIKE THEM SPREAD OUT A LITTLE BIT -
(22c) THEY’RE ALL 6 MONTH CERTIFICATES
(23) E: Yes
(24) H: And I don’t like putting all my eggs in one basket...
Centers cross segments

- Centers continued over discourse segment boundaries with pronominal referring expressions whose form is identical to those that occur within a discourse segment.
  - (29) and he's going to take a pear or two, and then.. go on his way
  - (30) um but the little boy comes,
  - (31) and uh he doesn't want just a pear,
  - (32) he wants a whole basket.
  - (33) So he puts the bicycle down,
  - (34) and he..
  - [Pear Stories, Chafe, 1980; Passonneau, 1995]:

  => discourse segment boundary between (32) and (33).

  [Walker et al., 1998], (33) realizes a CONTINUE transition, indicating that utterance (33) is highly coherent in the context of utterance (32).
Why is centering only within Segment?

- It is not plausible that a different process than centering would be required to explain the relationship between utterances (32) and (33), simply because these utterances span a discourse segment boundary.

- Centering is a theory that relates focus of attention, choice of referring expression, and perceived coherence of utterances, within a discourse segment [Joshi & Weinstein 1983, Grosz, Joshi & Weinstein, 1995],
Cache Model (Human Working Memory)

...that the data supports the conclusion that return pops are cued retrieval from main memory and that the cues reflect the context of the pop (Ratcliff and McKoon, 1988). Thus, return pops are not problematic for the cache model.

In the cache model, there are at least three possibilities for how the context is created so that pronouns in RETURN POPS can be interpreted: (1) The pronoun alone functions as a retrieval cue (Greene, McKoon, and Ratcliff, 1992); or (2) The content of the first utterance in a return indicates what information to retrieve from main memory to the cache, which implies that the interpretation of the pronoun is delayed; (3) The shared knowledge of the conversants creates expectations that determines what is in the cache, e.g. shared knowledge of the task structure.
Empirical Approaches: Comparison

- “A long-standing weakness in the area of anaphora resolution: the inability to fairly and consistently compare anaphora resolution algorithms due not only to the difference of evaluation data used, but also to the diversity of pre-processing tools employed by each system.” (Barbu & Mitkov, 2001)

- It is NOW customary to evaluate algorithms on the MUC-6 and MUC-7 coreference corpora.
  - [http://www.aclweb.org/anthology-new/M/M98/M98-1029.pdf](http://www.aclweb.org/anthology-new/M/M98/M98-1029.pdf)

- But there is very little annotated data for event/abstract anaphora.
- Lots of examples in our data. Let’s look for any sources
Dialogue & Discourse Data (circa 2010)

- Forums data
- Switchboard & Switchboard DAMSL
- Map Task (Edinburgh)
- Treebanked Maptask, Treebanked Switchboard
- Communicator Dialogs with Dialog Act Annotations
- Marcu RST corpus
- Penn Discourse Tree Bank
- Robocup soccer commentaries
- GIVE: generating instructions in virtual environments
- Referring Expression Challenge
- More all the time