Discourse and Dialog

Natural Language Processing
Language Technology
Week 13

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Discourse

• John is a mechanic and a nice man.

• John is a mechanic. He is a nice man.

• **monolog**: one speaker

• **dialog**: more than one speaker (usually two)
Discourse Tasks

• Discourse Structure or Coherence Structure
• Coherence analysis
• Co-reference Resolution
Coherence

• I am tired. I barely slept at all last night. I was up late writing this lecture.

• I am tired. John is a mechanic. He likes cheeseburgers.

• coherence: Adjacent sentences in a discourse are related to each other.

• coherence relations: how sentences are connected. Here, explanation.
Discourse Segmentation

• Simple version of coherence relations.

• Identify the start and end of each discourse segment.

• Discourse segment: semantically homogenous sequence of sentences.

• Used as pre-processing for information retrieval, information extraction, summarization.
Discourse Segmentation

• Three times a month, Mohammad al-Kirayfawai hands $300 to fighters from the Islamic State for the privilege of driving his refrigerated truck full of ice cream and other perishables from Jordan to a part of Iraq where the militants are firmly in charge.

• The fighters who man the border post treat the payment as an import duty, not a bribe.

• They even provide a stamped receipt, with the logo and seal of the Islamic State, that Mr. Kirayfawai, 38, needs for passing through other checkpoints on his delivery route.

• Refuse to pay and the facade of normality quickly falls away. “If I do not,” Mr. Kirayfawai explained, “they either arrest me or burn my truck.”

• Americans remain very overweight.

• According to the Centers for Disease Control and Prevention, about 38 percent of adults were obese in 2013-14, compared with 32 percent just 10 years ago.

• This is in spite of huge efforts to get people in the United States to eat more healthily.

• Canyon Lake Ranch was once a playground for Christian day campers, and then was a corporate retreat with water-skiing, barbecues and cowboy shoot-'em-up shows.

• Hawks now circle above 108 sunbaked acres occupied by copperhead snakes, a few coyotes and the occasional construction truck.

• Soon this ranch will be a gated subdivision of 99 mini-mansions designed for buyers from mainland China.

• The developer, Zhang Long, a Beijing businessman, is keeping three plots to build his own estate along the site of an old rodeo arena.
Discourse Segmentation

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Lexical Cohesion

- **Cohesion**: the use of linguistic devices to link textual units.

- **Lexical Cohesion**: Repetition, Synonymy, Hypernyms, Antonyms, Anaphor.

- **Cohesion chains**: the connection of multiple terms to maintain cohesion across multiple textual units (sentences)
TextTiling Algorithm

- Unsupervised Discourse Segmentation.

1. Tokenize the input document.

2. Calculate cosine similarity between term vectors extracted from overlapping regions

3. Identify valleys.
TextTiling

\[
sim_{\text{cosine}}(\vec{b}, \vec{a}) = \frac{\vec{b} \cdot \vec{a}}{|\vec{b}| |\vec{a}|}
\]

\[
sim_{\text{cosine}}(\vec{b}, \vec{a}) = \frac{\sum_{i=1}^{N} b_i * a_i}{\sqrt{\sum_{i=1}^{N} b_i^2} \sqrt{\sum_{i=1}^{N} a_i^2}}
\]
Supervised Discourse Segmentation

• Find labeled data for training.
  
  • `<p>` works pretty well…

• Identify candidates.
  
  • Sentence boundaries? Each word?

• Extract features from before and after the candidate boundaries.
  
  • LSA, Term vectors, Discourse Markers (“good evening”, “thus”), Proper names, etc.
Evaluating Segmentation

- Why not use accuracy?
- Why not use F-measure?
- **WindowDiff**: Calculate the number of probe regions in which the number of hypothesized segments differ.
Textual Coherence

• The coherence relation between a pair sentences.

• I am tired. I barely slept at all last night. I was up late writing this lecture.

• I am tired. John is a mechanic. He likes cheeseburgers.
Example Coherence Relations (Hobbs 1979)

• **Result:** the state or event asserted by S0 causes or could cause the state or event asserted by S1.

• The Tin Woodman was caught in the rain. His joints rusted

• **Explanation:** the state or event asserted by S1 causes or could cause the state or event asserted by S0

• John hid Bill’s car keys. He was drunk.
Example Coherence Relations

- **Parallel:** \( p(a_1,a_2...) \) from assertion of S0 and \( p(b_1,b_2,...) \) from assertion of S1 where \( a \) and \( b \) are similar.

  - The Scarecrow wanted brains. The Woodman wanted a heart.

- **Elaboration:** the same proposition \( P \) from assertions of S0 and S1

  - Dorothy was from Kansas. She lived in the midst of the great Kansas prairies.
Example Coherence Relations

- **Occassion:** A change of state can be inferred from the assertion of S0, whose final state can be inferred from S1, or a change of state can be inferred from the assertion of S1 whose initial state can be inferred from S0

- Dorothy picked up the oil can. She oiled the Woodman’s joints.
Example Coherence Structure

A. John went to the bank to deposit his paycheck
B. He then took a train to Bill’s car dealership
C. He needed to buy a car
D. The company he wore for now isn’t near any public transportation
E. He also wanted to talk to Bill about their softball league
Automatic Coherence Assignment

• Either between pairs of sentences (relation assignment), or a larger discourse (discourse parsing).

• Shallow algorithm:
  • Identify cue phrases.
  • Segment the text into discourse segments
  • Classify the relationships based on cue phrases.
Example Cue phrases

- Discourse connectives like **because** (indicates explanation relation)

  - John hid Bill’s car keys because he was drunk.

- Also: **although, therefore, but, for example, yet, with, and.**

- This segmentation will not necessarily be sentence based.

- Often bootstrapping (like in IE) is used to identify cue phrases.
Reference Resolution

• **co-reference resolution**: two different terms refer to the same referent

• **pronoun resolution**: identifying what term is referred to by a pronoun

• **Definite vs. Indefinite** referring expressions
  - Definite: identifiable in a given context.
  - Indefinite: not (necessarily) identifiable
Referring expressions

- **Indefinite Noun Phrases:** Introduce a new entity into the discourse.
  - I saw this guy yesterday.
  - He went around to bring her some food.
  - John sent a gift.

- **Definite Noun Phrases:** refer to entities that are *identifiable* to the hearer. Possibly because it’s already in the discourse.
  - I saw a missing sign for a white dog. But the white dog in the picture is my mom’s, and he’s fine.
  - I read about it in the paper.
Referring expressions

• **Pronouns:** form of definite reference. Requires that the referent have high salience.

  A. John went to Bob’s party, and parked next to a classic Ford Falcon.

  B. He went inside and talked to Bob for a while.

  C. Bob told him that he recently got engaged.

  D. He also said that he bought it yesterday.

  D. He also said that he bought the Falcon yesterday.

• Even before she saw it, Jane knew that she would love the gift. [cataphora]
Referring expressions

- **Demonstratives:** demonstrative pronouns like *this* and *that*. Indicate near or far-ness

  - I just bought a copy of Thoreau’s *Walden*. I had bought one five years ago. *That one* had been very tattered. *This one* was in much better condition.

- **Names:** can be used to refer to either old (given) or new entities in the discourse

  - **Miss Woodhouse** certainly had not done him justice.
Information Status

• Given vs. New. — Those entities in the discourse already vs. new entries.

• Discourse given/new — what a speaker believes about the state of the discourse

• Hearer given/new — what a speaker believes about the state of the hearer
Givenness hierarchy

• Givenness can also be sorted into levels of information status.

• in focus — *it*

• activated — *that, this, this N*

• familiar — *that N*

• uniquely identifiable — *the N*

• referential — indef. *this N*

• type identifiable — *a N*
More complications

- **Inferrables**: a discourse entity that can be inferred from a given entity.
  - My car drives great, but there are few dents in a door, and the muffler is busted.

- **Generics**: Don’t refer to specific entities
  - In January, you’re going to need snow boots.
  - I’m interested in getting an El Camino. They’re rad.

- **Non-referential uses**: sometimes referring terms like it can be used in non-referential ways.
  - It is raining.
  - It was John who called.
  - They really hit it off.
Pronoun resolution

• Simple version:

  • We have *prior* context, and a single pronoun. (no cataphora)

  • Find the antecedent
Filtering potential referents

- **Number agreement**: referring expressions and referent have to agree in number

  - I have a car. It is red.
  
  - I have a car. They are red.
  
  - I have two cats. They are red.
  
  - I have two cats and a dog. It is old and fat.
Filtering potential referents

- **Person agreement**: First, second, third person agreement.
  
  - *He, she, they* must refer to third person antecedents.
  
  - I work at home. He is getting cabin fever.

- **Gender agreement**: English has male, female and neuter (non-personal) genders.
  
  - John has a car. It is really good-looking.
  
  - John has a car. He is really good-looking.
Filtering potential referents

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  - *He, she, they* must refer to third person antecedents.
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Filtering potential referents

- **Binding theory constraints**: Syntactic constraints about pronominalization

  - Reflexives (himself, myself, etc.) corefer with the subject of the most immediate cause. Non-reflexives cannot.
    - John bought himself a new Ford. [himself = John]
    - John bought him a new Ford [him ≠ John]
    - A full NP subject cannot cohere with the subject of the most immediate clause or with a higher-level subject
      - He said that he bought John a new Ford. [he ≠ John]
Preferences in Pronoun Interpretation

• **Recency**: Entities in recent utterances are more salient than older entities.

  • The doctor found an old map in the captain’s chest. Jim found an even older map on the shelf. It described an island.

• **Grammatical Role**: subjects are (typically) more salient than objects (which are more salient than other positions).

  • John went to dinner with Bob. He had a steak.
Preferences in Pronoun Interpretation

- **Repeated Mention:** an antecedent that has been referred to will continue to be.

- Bill had been thinking about rum ever since the pirate ship docked. He hobbled over to the bar. Jim went with him. He called for a glass of rum.

- **Parallelism:** parallel constructions typically refer to the same entity

- John went with Jim to the Old Parrot. Bill went with him to the Old Anchor in.
Preferences in Pronoun Interpretation

• **(Verb) Semantics:** some verbs provide emphasis on one argument or another.

  • Jim blamed Bill. He lost the game.
  
  • Jim confessed to Bill. He lost the game.

• **Selectional Restrictions:** verbs place restrictions on arguments which can filter antecedents

  • John parked his car in the garage after driving it for hours. \([it \neq \text{garage}]\)
Algorithms for Anaphora Resolution

• Hobbs Algorithm
• Centering Algorithm
• Supervised Classification
Hobbs Algorithm

• Deterministic Algorithm

• Derived from recency, grammatical role and binding theory preferences.

• Input: Parse tree, gender and number assignments for each Noun and Pronoun

1. Start at the NP dominating the pronoun

2. Go up the tree to the first NP or S found. Call this node X and the path p

3. Traverse all branches below node X to the left of p (BFS). Propose as a candidate, any NP that has an NP or S between it and X

4. Iff X is the root, traverse trees of previous sentences (BFS). Propose any NP found.

5. From X go up the tree to the first NP or S found. Call this new node X and the path p

6. If X is an NP and the path p to X didn’t pass through the Nominal that X dominates, propose X.

7. Traverse all branches below X to the left of p (BFS) Propose any NP

8. If X is an S node, traverse all branches of node X to the right of p (BFS), but don’t go below any NP or S. Propose any NP.

Centering algorithm

• Explicit Discourse Model.

• Each utterance has a “center” describing the focused entity.

• **backward-looking center**, $C_b(U_n)$: the entity being focused on when $U_n$ is interpreted.

• **forward-looking centers**, $C_f(U_n)$, an ordered list of entities mentioned in $U_n$ that could be backward looking centers for $U_{n+1}$.

• Under the theory $C_b(U_{n+1}) = C_p(U_n) = C_f(U_n).\text{top}()$ or the highest ranked forward looking center from the previous utterance.

• Ranking centers: subject > existential predicate nominal > object > indirect object or oblique > demarcated adverbial PP
Centering algorithm

• Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.

B. He showed it to Bob.

C. He bought it.

• \( C_f(A) = ?? \)

• \( C_b(A) = ?? \)
Centering algorithm

- Define 4 transition states between adjacent utterances

<table>
<thead>
<tr>
<th>Transition State</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_b(U_{n+1}) = C_b(U_n)$ or $C_b(U_n)$ undef.</td>
<td>$C_b(U_{n+1}) \neq C_b(U_n)$</td>
</tr>
<tr>
<td>$C_b(U_{n+1}) = C_p(U_{n+1})$</td>
<td>Continue</td>
</tr>
<tr>
<td>$C_b(U_{n+1}) \neq C_p(U_{n+1})$</td>
<td>Smooth-Shift</td>
</tr>
<tr>
<td>$C_b(U_{n+1}) \neq C_p(U_{n+1})$</td>
<td>Retain</td>
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<tr>
<td>$C_b(U_{n+1}) \neq C_p(U_{n+1})$</td>
<td>Rough-Shift</td>
</tr>
</tbody>
</table>

- Rules:
  - If any element of $C_f(U_n)$ is realized by a pronoun in $U_{n+1}$, then $C_b(U_{n+1})$ must be realized by a pronoun too.
  - Transition states are ordered: Continue > Retain > Smooth-Shift > Rough-Shift
Centering algorithm

<table>
<thead>
<tr>
<th>Condition</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>$C_b(U_{n+1}) = C_b(U_n)$ or $C_b(U_n)$ undef.</td>
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</tr>
<tr>
<td></td>
<td>Rough-Shift</td>
</tr>
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</table>

1. Generate all Cb-Cf combinations for each possible set of assignments.

2. Filter by constraints, coreference, selectional restrictions, centering rules, etc.

3. Rank by transition orderings.
Centering algorithm

• Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.

B. He showed it to Bob.

C. He bought it.

• $C_f(A) = \{\text{John, Ford Falcon, dealership}\}$

• $C_p(A) = \text{John}$

• $C_b(A) = \text{undef.}$
Centering algorithm

• Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.
B. He showed it to Bob.
C. He bought it.

• $C_f(B) = \{\text{John, Ford, Bob}\} \rightarrow \text{He} \rightarrow \text{John (only choice). It} \rightarrow \text{Ford (try it out.)}$

• $C_p(B) = \text{John}$

• $C_b(B) = \text{John} \rightarrow \text{highest ranked member of } C_f(A) \text{ mentioned in B}$

• Result: ???
Centering algorithm

- Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.

B. He showed it to Bob.

C. He bought it.

- $C_f(B) = \{\text{John, dealership, Bob}\} \rightarrow \text{He} \rightarrow \text{John (only choice). It} \rightarrow$ dealership (try it out.)

- $C_p(B) = \text{John}$

- $C_b(B) = \text{John} \rightarrow \text{highest ranked member of } C_f(A) \text{ mentioned in } B$

- Result: ???
Centering algorithm

- Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.

B. He showed it to Bob.

C. He bought it.

- \( C_f(C) = \{\text{John, Ford Falcon}\} \) — He -> John (try it out). It -> Ford (from decision about B)

- \( C_p(C) = \text{John} \)

- \( C_b(C) = \text{John} \) — highest ranked member of \( C_f(B) \) mentioned in C

- Result: Continue
Centering algorithm

• Example Discourse

A. John saw a beautiful 1961 Ford Falcon at the used car dealership.

B. He showed it to Bob.

C. He bought it.

• $C_f(C) = \{\text{Bob, Ford Falcon}\}$ — He $\rightarrow$ Bob (try it out). It $\rightarrow$ Ford (from decision about B)

• $C_p(C) = \text{Bob}$

• $C_b(C) = \text{Bob}$ — highest ranked member of $C_f(B)$ mentioned in C

• Result: Smooth-Shift
Supervised Learning

• Require labeled data: matched pronouns and antecedents.
  • Negative examples?

• Input: pronoun, current and previous sentences
  • Extract all potential antecedents (NPs)
  • Classify each NP, pronoun pair.

• Features:
  • **Strict/Compatible Number**: how tight a number match?
  • **Strict/Compatible Gender**: how tight a gender match?
  • **Sentence Distance**: how many sentences separate pronoun from NP
  • **Hobbs Distance**: number of noun groups skipped by Hobbs algorithm
  • **Grammatical Role**: subject, object, PP
  • **Linguistic Form**: proper, definite, indefinite, pronoun

• This is also used for co-reference resolution
Dialog

• Conversation between two (or more) participants.

• Dialog (or conversation) is a particular type of discourse.

• What makes dialog distinct?
Dialog

- Turn-taking
- Speech Acts
- Grounding
- Conversational Implicature
Turn-Taking

• How do we determine whose turn it is to talk?

• Within conversation there are transition-relevant places (TRP) where a turn change could happen.

• One Theory: At each TRP:

  • If the current speaker has selected A as the next speaker, then A must speak next.

  • If the current speaker does not select the next speaker, any speaker may take the turn.

  • If no one else takes the turn, the current speaker may take it.
Speech Acts

• Language conveys information.

• An utterance is an action performed by the speaker.
  
  • **Locutionary act**: The utterance of a sentence with particular meaning

  • **Illocutionary act**: The act of asking, answering, promising, by uttering a sentence

  • **Perlocutionary act**: The production of certain effects upon the feelings, thoughts, or actions of the addressee
Illocutionary acts

• **Assertives**: commit the speaker to something being true *suggesting, swearing, concluding*

• **Directives**: attempts to get the addressee to do something. *asking, ordering, requesting, inviting*

• **Commissives**: committing the speaker to do something *promising, vowing, betting*

• **Expressives**: expressing the state of the speaker *apologizing, welcoming, thanking*

• **Declarations**: changing the state of the world by the utterance *you’re fired. I quit. I name this dog, “Buster”.*
Grounding

• When we speak, we seek to establish **common ground**. (Discourse state)

• **Principle of closure** (Clark 1996) Agents performing an action require evidence that they have succeeded in performing it.

1. **Continued attention**: B shows she is continuing to attend and therefore remains satisfied with A’s presentation.

2. **Relevant next contribution**: B starts in on the next relevant contribution.

3. **Acknowledgement**: B nods or says a continuer like *uh-huh, yeah*, or the like, or an assessment like *that’s great*.

4. **Demonstration**: B demonstrates all or part of what she has understood A to mean, for example by paraphrasing or reformulating A’s utterance, or by collaboratively completing A’s utterance.

5. **Display**: B displays verbatim all or part of A’s presentation
Conversational Implicature

• Meaning in conversation is trickier than meaning in monolog.

• And what day in May did you want to travel?

• OK uh I need to be there for a meeting that’s from the 12th to the 15th.

• There’s three non-stops today.
Grice's Maxims

- **Maxim of Quantity:**
  - Be exactly as informative as required.
  - Do not make your contribution more informative than is required.

- **Maxim of Quality**
  - Do not say what you believe to be false.
  - Do not say that for which you lack adequate evidence.

- **Maxim of Relevance**
  - Be relevant.

- **Maxim of Manner**
  - Avoid ambiguity.
  - Avoid obscurity of expression.
  - Be brief.
  - Be orderly.
Structure of a Dialog System

- Speech Recognition
- Natural Language Understanding
- Text-to-Speech Synthesis
- Natural Language Generation
- Dialog Manager
- Task Manager
Natural Language Understanding

- **Natural Language Understanding**: Convert user input to a semantic representation

- **Task Manager**: external system determining the task. I.e. making reservations.

- **Natural Language Generation**: Convert system semantics to lexical form
Dialog Manager

- Controls the structure of the dialog.
- Simplest: Finite State Machine (dialog flow chart)

1. From what city?
2. Where are you going?
3. When do you want to leave?
4. One way or round trip?
5. Do you want to go FROM to TO on DATE?
6. When do you want to return?
7. Do you want to go FROM to TO on DATE1 returning on DATE2?
8. book the flight
Frame Based Dialog Manager

• Fill in the required slots
  • ORIGIN CITY:
  • DESTINATION CITY:
  • DEPARTURE DATETIME:
  • ARRIVAL DATETIME:

• Ask appropriate questions to elicit fills or confirm for each slot. But information can come in any order.
Initiative

*System Initiative*: The dialog is driven by the system asking the user for information

*User Initiative*: Start with a relatively open prompt. “How may I help you?” “What’s up?”

*Mixed Initiative*: A combination of prompt types. Open up a wide range for users to offer information in different orders and styles, but allow the system to prompt for specific elements.
Dialogue Acts

- It can be useful in a dialog system to recognize different types of user behavior as **dialog acts**.

<table>
<thead>
<tr>
<th>Dialogue Act</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>THANK</td>
<td>Thanks</td>
</tr>
<tr>
<td>GREET</td>
<td>Hello Dan</td>
</tr>
<tr>
<td>INTRODUCE</td>
<td>It’s me again</td>
</tr>
<tr>
<td>BYE</td>
<td>OK, bye</td>
</tr>
<tr>
<td>REQUEST-COMMENT</td>
<td>How does that work?</td>
</tr>
<tr>
<td>SUGGEST</td>
<td>from 13th to the 17th</td>
</tr>
<tr>
<td>REJECT</td>
<td>No, I’m busy on Friday</td>
</tr>
<tr>
<td>ACCEPT</td>
<td>Saturday will work</td>
</tr>
<tr>
<td>REQUEST-SUGGEST</td>
<td>What is a good day for you?</td>
</tr>
<tr>
<td>INIT</td>
<td>I’d like to book an appointment</td>
</tr>
<tr>
<td>GIVE-REASON</td>
<td>I’m in meetings all day</td>
</tr>
<tr>
<td>FEEDBACK</td>
<td>OK</td>
</tr>
<tr>
<td>DELIBERATE</td>
<td>one sec. let me check</td>
</tr>
<tr>
<td>CONFIRM</td>
<td>yeah, that’s great</td>
</tr>
<tr>
<td>CLARIFY</td>
<td>do you mean tuesday the 15th?</td>
</tr>
<tr>
<td>DIGRESS</td>
<td>we could go for coffee after</td>
</tr>
<tr>
<td>MOTIVATE</td>
<td>we should visit Boston next week</td>
</tr>
<tr>
<td>GARBAGE</td>
<td>oops, i mean. sorry.</td>
</tr>
</tbody>
</table>

(from verbmobil)
Recognizing Dialog Acts

• Again typically done with supervised machine learning

• Three types of features

1. **Words and Grammar**: *please* or *would you* indicates a *request*. *are you* for *yes-no-question*. *word and pos n-grams*

2. **Prosody**: Rising pitch for *yes-no-question*. Final lowering for *statements* and *wh-questions*. Loudness to distinguish *agreement* from *backchannel*.

3. **Conversational Structure**: *yeah* following a *proposal* is more likely to be an *acknowledgment*. *dialog act bi-grams*
Markov Decision Processes

- Treat task satisfaction as a **goal** and dialog actions to be **actions** that impact the discourse **state**.

- This is a standard planning problem. (Classic AI).

- Markov Decision Process (MDP)
  
  - \( S \) a set of states
  
  - \( A \) a set of actions
  
  - \( r(a,s) \) a reward for each action.

- Example objective function:
  
  \[ R = -(w_i n_i + w_e n_e + w_f n_f) \]

  - \( i \) - num turns,
  
  - \( e \) - num errors,
  
  - \( f \) - num slots filled
Markov Decision Processes

- Explore all possible action paths and optimize the reward function.

- Actions and states do not deterministically result in a target state.

- Use a probability of state transition and discounted estimate of future reward.

\[
Q(s, a) = R(s, a) + \gamma \sum_{s'} P(s' | s, a) \max_{a'} Q(s', a')
\]

- How do you train this? How to find labeled data to estimate \( p(s' | s, a) \)?