CMPT-413
Computational Linguistics

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Discourse Processing

- Multiple sentences, dialogs
- Human-human (Switchboard corpus) and human-computer interaction (ATIS corpus)
- New phenomena at the discourse level:
    1. John went to Bill's car dealership to check out an Acura Integra. He looked at it for about an hour.

Discourse Structure

- Consider a sequence of sentences: `s1, s2, ...`.
- Such a sequence is structured based on various relationships between the sentences.
- The discourse structure is a tree expressing these relationships:

```
(DISCOURSE (DR1 (S1 [s1])
                (DR2 (S2 [s2])
                     (S3 [s3]))
                (S4 [s4]) ... )
```

Discourse Structure

- Each DR*i* is some discourse relationship, e.g.

```
(COMPARISON
  (S1 [Bill drove his old car from BC to Quebec])
  (TEMPORAL-SEQUENCE
    (S2 [On the other hand, John bought a new car])
    (S3 [Then, he drove it across the country to Quebec])))
```

- These tree structures can be described by writing down context-free grammar rules, but in this case capturing rules of discourse structure (distinct from rules of sentence structure).

Reference Resolution

- In the previous discourse: *John, Bill, Acura Integra, car dealership* are all **discourse entities**.
- Anaphors like *he, she, it* are **referring expressions**, e.g. *John* and *he* **corefer**. A group of referring expressions that corefer is called a **coreference chain**.
- Each discourse entity can refer to one or more entities in the real world.
- Keeping track of discourse entities and relationships between them across multiple sentences is the job of the **discourse model**.

Types of Referring Expressions

- **Indefinite Noun Phrases**: *specific* vs. *non-specific* indefinites:
  I saw this great looking car today vs. *Mary is going to marry a Swede*
- **Definite Noun Phrases**: refers to an existing entity
  I saw an Acura Integra and a Mercedes today. The Integra was white.
  what about: *I'm going to take the bus today*
- **Pronouns**: locality effects, occurs later in the discourse than the entity it refers to:
  I saw an Acura Integra and a Mercedes today. It was white.
  cataphora: *Before he bought it, John test-drove his Acura.*

Types of Referring Expressions

- **Demonstratives** (also called *deictic* pronouns)
  I like this better than that.
- **One Anaphora** (one of them)
  I saw six Acura Integras today. Now I want one.
- **Inferrables** (no explicit discourse entity to refer to)
  I almost bought an Acura Integra today. But a door was dented and the engine was noisy.

Types of Referring Expressions

- **Discontinuous Sets** (plural referring expressions):
  John has an Acura and Mary has a Mazda. They drive them all the time.
- **Generics** (refer to a class of objects):
  I saw no less than six Acura Integras today. They are the coolest cars.

Syntactic and Semantic Constraints on Reference

- Person, Number, Gender and Case agreement.
  John has a new Acura. It is red.
- Syntactic constraints:
  John bought himself a new Acura. [himself=John] (**reflexives**)
  John bought him a new Acura. [him$\neq$John]
- Pleonastic *It*: A pronoun that has no reference:
  It is raining

Syntactic and Semantic Constraints on Reference

- These constraints apply in practice to rule out certain coreference possibilities:
  John wanted a new car. Bill bought him a new Acura.
  [him=John]
  John wanted a new car. He bought him a new Acura.
  [he=John,him≠John]
- Selectional restrictions:
  John parked his Acura in the garage. He had driven it around for hours.
  (not always) *John bought a new Acura. It drinks gasoline like a fish.*

Preferences in Pronoun Resolution

- **Recency**: *John has an Integra. Bill has a Legend. Mary likes to drive it.*
- **Grammatical Role**: subject > existential predicate NP > object > indirect object > nouns in adverbial PP
  - An Acura Integra is parked in the lot. (subject)
  - There is an Acura Integra parked in the lot. (existential predicate NP)
  - John parked an Acura Integra in the lot. (object)
  - John gave his Acura Integra a wash. (indirect object)
  - Inside his Acura Integra, John installed a new CD player. (adv. PP)

Preferences in Pronoun Resolution

- **Repeated Mention**: entities referred to as pronouns are likely to continue being used as pronouns
- **Parallelism**: (cf. grammatical role)
  Mary went with Sue to the car dealership. Sally went with her to the market.
- **Verb Semantics**:
  John telephoned Bill. He had lost the pamphlet.
  John criticized Bill. He had lost the pamphlet.

Centering Theory and an Algorithm for Pronoun Resolution

- Centering Theory (Grosz et al., 1995) is a theory of local attention and how it changes over time in a discourse
- It makes the claim that a single entity is being *centered* at any given point in the discourse (the point of attention)
- First we represent the discourse within a discourse model, and then we use this representation for pronoun resolution
- Let U_n and U_{n+1} represent adjacent utterances in a discourse.

Centering

- The *backward looking center*: $C_b(U_n)$ of utterance U_n is the entity that is being focused on after U_n is interpreted.
- The *forward looking centers*: $C_f(U_n)$ of utterance U_n is an ordered list of entities that are possible candidates for $C_b(U_{n+1})$.
  The ordering can be one of the preferences given above (e.g. the grammatical role hierarchy) or a combination of preferences.
- $C_b(U_{n+1})$ is defined as the most highly ranked entity in the list $C_f(U_n)$ *mentioned in* U_{n+1}. The C_b of the first utterance is undefined.
  The most highly ranked entity before we see U_{n+1} is called $C_p(U_n)$, the preferred center.

Centering

- Centering then defines relationships between utterances as a function of the relation between the backward center and the preferred center
- These transitions provide a theory of **text coherence**

	$C_b(U_{n+1}) = C_b(U_n)$ or undefined $C_b(U_n)$	$C_b(U_{n+1}) \neq C_b(U_n)$
$C_p(U_{n+1}) = C_b(U_{n+1})$	Continue	Smooth-Shift
$C_p(U_{n+1}) \neq C_b(U_{n+1})$	Retain	Rough-Shift

Centering for Pronoun Resolution

- The following rules are used by the algorithm (Brennan et al. ACL 1987):
  1. If any element of $C_f(U_n)$ is realized by a pronoun in utterance U_{n+1}, then $C_b(U_{n+1})$ must also be realized by a pronoun.
  2. Transition states are ordered by preference: Continue $>$ Retain $>$ Smooth-Shift $>$ Rough-Shift.

Centering for Pronoun Resolution

- The algorithm for pronoun resolution is defined as follows:
  1. Generate possible $C_b - C_f$ combinations for each possible set of reference assignments.
  2. Filter by constraints, e.g. if some assignments are illegal due to syntactic or semantic constraints remove them from consideration.
  3. Rank by transition orderings.

Centering for Pronoun Resolution

- Consider the following discourse:
  - John saw a beautiful Acura Integra at the dealership. (U_1)
  - He showed it to Bob. (U_2)
  - He bought it. (U_3)
- For sentence U_1 we get:

$$
\begin{aligned}
C_f(U_1) &: \quad \{\text{John, Integra, dealership}\} \\
C_p(U_1) &: \quad \text{John} \\
C_b(U_1) &: \quad \text{undefined}
\end{aligned}
$$

Centering for Pronoun Resolution

- For sentence U_2 we have two options for *it*. Option 1:

$$\begin{aligned} C_f(U_2): &\quad \{\text{John, Integra, Bob}\} \\ C_p(U_2): &\quad \text{John} \\ C_b(U_2): &\quad \text{John} \end{aligned}$$

  Result: Continue $\Rightarrow C_p(U_2) = C_b(U_2)$; $C_b(U_1)$ undefined

- Option 2:

$$\begin{aligned} C_f(U_2): &\quad \{\text{John, dealership, Bob}\} \\ C_p(U_2): &\quad \text{John} \\ C_b(U_2): &\quad \text{John} \end{aligned}$$

  Result: Continue $\Rightarrow C_p(U_2) = C_b(U_2)$; $C_b(U_1)$ undefined

Centering for Pronoun Resolution

- For sentence U_3 we have two options for *he*. Option 1:

$$\begin{aligned} C_f(U_3): &\quad \{\text{John, Integra}\} \\ C_p(U_3): &\quad \text{John} \\ C_b(U_3): &\quad \text{John} \end{aligned}$$

  Result: Continue $\Rightarrow C_p(U_3) = C_b(U_3) = C_b(U_2)$ – preferred

- Option 2:

$$\begin{aligned} C_f(U_3): &\quad \{\text{Bob, Integra}\} \\ C_p(U_3): &\quad \text{Bob} \\ C_b(U_3): &\quad \text{Integra} \end{aligned}$$

  Result: Rough-Shift $\Rightarrow C_p(U_3) \neq C_b(U_3); C_b(U_3) \neq C_b(U_2)$

Centering for Pronoun Resolution

- Another example:
  - Who is Max waiting for? (U_1)
  - He is waiting for Fred. (U_2)
  - He invited him for dinner. (U_3)
- For sentence U_1 we get:

$$\begin{aligned} C_f(U_1):&\quad \{\text{Max}\} \\ C_p(U_1):&\quad \text{Max} \\ C_b(U_1):&\quad \text{undefined} \end{aligned}$$

- For sentence U_2 by assigning *he* to *Max* (the only option) we get:

$$\begin{aligned} C_f(U_2):&\quad \{\text{Max, Fred}\} \\ C_p(U_2):&\quad \text{Max} \\ C_b(U_2):&\quad \text{Max} \end{aligned}$$

Centering for Pronoun Resolution

- For sentence U_3 we have two options for *he* and *him*
  Either *he* $=$ *Max* and *him* $=$ *Fred* OR *he* $=$ *Fred* and *him* $=$ *Max*
- Note that there are only two options for reference and not four due to the syntactic constraint on binding the pronouns.
  Ruled out: *he* $=$ *Max* and *him* $=$ *Max* OR *he* $=$ *Fred* and *him* $=$ *Fred*
  Option 1:

$$\begin{aligned} C_f(U_3):&\quad \{\text{Max, Fred}\} \\ C_p(U_3):&\quad \text{Max} \\ C_b(U_3):&\quad \text{Max} \end{aligned}$$

  Result: Continue $\Rightarrow C_p(U_3) = C_b(U_3) = C_b(U_2)$ – preferred
- Option 2:

$$\begin{aligned} C_f(U_3):&\quad \{\text{Fred, Max}\} \\ C_p(U_3):&\quad \text{Fred} \\ C_b(U_3):&\quad \text{Max} \end{aligned}$$

  Result: Retain $\Rightarrow C_p(U_3) \neq C_b(U_3); C_b(U_3) = C_b(U_2)$

Pronoun Resolution Algorithms

- Centering is one route towards a pronoun resolution algorithm. There are many others including the Lappin and Leass algorithm and the Hobbs Algorithm (see J&M Chp. 18).
- Accuracy is measured in terms of the number of co-reference chains that are recovered correctly.
- Annual competition on co-reference is held as part of the Message Understanding Conference (MUC)

Dialog Systems

- So far, we have looked at multiple utterances, but not at dialog
- Dialog is different:
  - Turn Taking
    (usually handled using canned text in current dialog systems)
  - Common Ground
  - Conversational Implicature

Common Ground

- As conversation proceeds, the speaker and hearer share a common set of information. They also share common world knowledge.
- If there is a problem in reaching common ground, the dialog needs to contain some indicators like **continuers** or **backchannels**.
- Often repeats or reformulations are used in dialog systems to establish common ground:
  A: Ok. I'll take the 5ish flight on the night before on the 11th.
  B: On the 11th?

Conversational Implicature

- Scalar implicature: *He dresses even worse than Anoop.*
- If the dialog system hears: *I want 3 stops in my itinerary.* – should it report on flights that have 7 stops?
  clearly not. why not?
- If the system asks: *And on what day would you like to travel?* and the user responds: *I need to be there for a meeting from the 12th to the 15th*
  why is the user's response taken to be relevant?

Conversational Implicature

- Common inferences in discourse (called **Grice's Maxims**):
  - *Quantity*: Be exactly as informative as required
    rules out certain entailments that usually apply: *3 stops* does not mean *7 stops*.
  - *Quality*: your contribution will be assumed to be true.
  - *Relevance*: your contribution is assumed to be relevant to the current situation. *Take the user response to mean the 11th*.
  - *Manner*: do not repeat yourself if you know something exists in the common ground.

Summary

- Dealing with multiple sentences provide new challenges: new phenomena at the discourse level.
- Discourse structure: relationship between sentences. Is it analogous to relationship between words?
- Pronoun resolution: incorporate syntactic and semantic constraints and other preferences.
- Centering: an approach to automate pronoun resolution.
- Multiple sentences with turn-taking: dealing with dialog between multiple participants.
- Dealing with pragmatic assumptions during planning what to say and how to understand.