Computational Linguistics: Discourse Model

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Contents

1. Discourse

So far we have looked at language phenomena that operate at the word or sentence level. But languages do not consist of isolated and unrelated sentences, rather of **group of sentences**, called discourse.

Finding a formal representation of discourse and build a computational model for it are challenging goals.

The questions to ask are

1. "How do we understand discourse?"
2. "How can we represent the meaning of discourse?"
3. "How do we compose discourse representation"?

1.1. Some challenging problems of Discourse

- The couple that won the dance contest was pleased
- Jody loves her husband
- Vincent regrets that Mia is married

These examples force us to take something for granted:

- There is a couple that won the dance contest
- Jody is married
- Mia is married

How do we know this? Have we entailed it from the sentences above?

1.2. Some challenging problems of Discourse (Cont'd)

Given contexts with contrary information

- Jody is not married. ?? She loves her husband.
- Mia is not married. ?? Vincent regrets that Mia is married.

these sentences do not make sense at all:

Whatever we're dealing with here, it is not ordinary entailment.

Both:

- Jody loves her husband.
- Jody does not love her husband.

imply that Jody is married.

We are dealing with presuppositions!

1.2.1. Presupposition

The sentences

- "Jody loves her husband"
- "Jody doesn't love her husband"

both imply that Jody has a husband.

We say that "Jody has a husband" is **presupposed** by these sentences.

This presupposition is triggered by the possessive pronoun "her".

1.2.2. Neutralize Presupposition

Complex sentences sometimes neutralize presuppositions.

(1) Mia's husband is out of town

it presupposes that Mia is married.

(2) If Mia has a husband, then Mia's husband is out of town.

it doesn't presuppose that Mia is married.

(3) If Mia dates Vincent, then Mia's husband is out of town.

it does!

1.3. Accommodation

We read the sentence: "Vincent informed his boss."

- Presupposition: Vincent has a boss.
- What if we don't have a clue whether Vincent has a boss or not?

We have to **incorporate missed information** as long as this not conflict with other information. This process is called "Accommodation"

Accommodation can be thought of as a way of obtaining a robust and realistic treatment of presupposition.

1.4. Which meaning representation?

We cannot just connect the first-order representations of the individual sentences.

1. Mia is a woman. She loves Vincent.
   - A: $woman(mia) \wedge love(x, vincent)$
   - B: $woman(mia) \wedge love(mia, vincent)$
2. A woman snorts. She collapses.
   - A: $\exists y(woman(y) \wedge snort(y)) \wedge collapse(x)$
   - B: $\exists y(woman(y) \wedge snort(y)) \wedge collapse(y)$
   - C: $\exists y(woman(y) \wedge snort(y) \wedge collapse(y))$
3. If a woman snorts, she collapses.
   - A: $\exists y(woman(y) \wedge snort(y)) \rightarrow collapse(x)$
   - B: $\exists y(woman(y) \wedge snort(y)) \rightarrow collapse(y)$
   - C: $\exists y(woman(y) \wedge snort(y) \rightarrow collapse(y))$
   - D: $\forall y(woman(y) \wedge snort(y) \rightarrow collapse(y))$

1.5. Which meaning representation?

- We need to start with the right representation
- Basic FOL does not seem to give us the right means, in particular, it does not provide means for:
  - Manipulation with quantifier scope and free variables
  - Not the right intuitions about how discourse works
- We need a representation that naturally mirrors the **context change potential** of an utterance.

The important components in the understanding of Discourse are: (i) the context and (ii) the knowledge shared by the hearer and speaker.

2. Discourse: Context

- Today, a rabbit came in our garden.

  a. He ate all the carrots.

  b. The rabbit was hungry.

Notice that the meaning we take a text to convey is context-dependent: "today", "our" are interpreted relative to the **non-linguistic context.**

"He", "all the carrots", "The rabbit" are interpreted relative to the context created by the **previous discourse**.

3. Context: Knowledge

The Context includes Speaker's Knowledge (SK) and Hearer's Knowledge (HK).

The shared knowledge (SK − HK) is called Common Ground (CG).

The **meaning conveyed**

- is part of the S_{context} ($\subseteq$ SK).
- Given meaning $\subseteq$ Common Ground
- New meaning SK − CG

The hearer attempts to synthesize the mental model of the speaker. She updates her context in response to the speaker's utterance.

Given and new meanings are realized in different ways.

- New is realized explicitly and non-anaphorically.
- Given is realized implicitly (through inference) and anaphorically.

3.1. Implicit Information

Implicit information results from different types of inferences:

Entailments i.e. propositions that are entailed by the context. e.g., "Bugs have four legs" entails "Bugs have two legs".

Implicatures i.e. (roughly) a proposition that is implied by a context, though not entailed. e.g., "Bugs have five carrots" implicates "Bugs have no more than five carrots".

Presuppositions i.e. propositions that are either entailed or consistent with the current context. e.g., "Bugs regrets eating all his carrots" presupposes "Bugs ate all his carrots".

3.2. Anaphoric Information

a. Some rabbits came in. Some rabbit ate all the carrots.

b. Some rabbits came in. They ate all the carrots.

(a) Indefinite brings in NEW information

(b) Pronoun is tied to GIVEN information

4. Consequence for understanding

The context is used to understand semantically or pragmatically underspecified expressions. In particular:

- Anaphoric expressions must be resolved.
- Implicit information must be inferred.

For instance, in “Jon has a rabbit. The tail is white and fluffy”.

- Anaphoric: The tail is anaphoric.
- Inference: Most rabbits have a tail, hence Jon’s rabbit has a tail
- Resolution of the definite: the tail; Jon’s rabbit.

We look for a theory to represent discourse that is able to take this observations into account.

5. Discourse Model

We have seen that discourse is understood with respect to a context including the speaker/hearers beliefs, knowledge, goals etc. In particular, discourse participants build a representation of discourse (Discourse Model) as part of the common ground.

The important questions to ask are:

1. What is a discourse model?
2. What is in a discourse model?
3. How long do items stay in the DM?
4. How does a DM come about?
5. How is the DM organized?

5.1. Intuitive answers

Discourse model: set of entities evoked by (or inferrable from) discourse + relations they participate in.

Discourse entity: "conceptual coathook" on which to hang descriptions of the entity's correspondent in the real or the hypothetical world.

5.2. Entities

The entities we can refer to are:

- Individuals e.g., the carrot
- Sets of Individuals e.g., three carrots, 3 pounds of carrots
- Masses e.g., water
- Eventualities e.g., The destruction of Paris
- Time points and intervals e.g., at 3 oclock, on Monday

The properties of entities are influenced by the **logical structure** of the semantic representation of their invoking sentence and specifically by:

- Quantifier scope
- Collective and distributive readings

5.2.1. Quantifier scope

- Mary showed each boy **an apple**.

  a. The apple was a MacIntosh.

  b. Then she mixed the apples up and had each boy guess which was his.

"an apple" evokes two distinct discourse entities depending on the respective scope of the quantifiers:

a. The apple Mary showed each boy

b. The set of apples each of which was shown by Mary to one of the boys.

5.2.2. Distributive vs. collective

- The three boys ordered **a large pizza**.

  a. Because of the heavy traffic, it was delivered cold.
  b. Because of the heavy traffic, they were delivered cold.

a. "it" $\rightsquigarrow$ The just mentioned large pizza that the 3 boys ordered.

b. "they" $\rightsquigarrow$ The just mentioned set of pizzas, each of which was ordered by one of the 3 boys.

5.2.3. Referring expressions Discourses are generally about these entities and the linguistics inputs have expressions referring to them. The most common are:

Anaphors: very specific **reflexive pronouns** ('himself', 'herself',) which are used to refer to something which is mentioned in the current sentence.

Pronouns: are used for referring to items that have been mentioned very recently, and which can be picked out on the besis of very simple characteristics properties.

Definite NPs: expressions like "the man" or "the pub in Maidenhead where we met your ex-husband" are often used for referring to entities which are known to all the discourse participants, and where furthermore all the participants in question fits the description provided. Note, that while the first one is rather like a pronoun, in that it can only be successfully used in context where some man has been mentioned reasonably recently, the second one can be used in almost any situation.

5.3. Accessibility

1. A woman snorts. She collapses
2. **Every** woman snorts. *She collapses

1. Mia ordered a five dollar shake. Vincent tasted it.
2. Mia **didn't** order a five dollar shake. Vincent tasted *it.

1. Butch_1 threw a TV_2 at the window_3. $\text{It}_{\{2,3\}}$ broke.
2. Butch_1 threw a vase_2 at the wall_3. It_2 broke.
3. Butch_1 walks into his_1 modest kitchen_2. He_1 opens the refrigerator_3. He_1 takes out a milk_4 and drinks it_4.

1. Vincent_1 goes to the toilet, and Jules_2 think of himself_2.
2. Vincent_1 enters the restaurant, and Jules_2 watches him_1.

A theory of Discourse Representation must be able to account for these facts.

6. Discourse Representation Theory

Based on the above observations in '81 Kamp developed Discourse Representation Theory (DRT) (Kamp 81; Kamp & Reyle 93).

The main idea of this theory is that meaning is a relation between contexts. From this, it follows that:

- Meaning is dependent on context
- Meaning can change context

DRT employs a language based on boxlike structures called Discourse Representation Structures (DRSs)

- DRSs are Pictures (something like "mental models")
- DRSs are Programs (the dynamic perspective)

6.1. Discourse Representation Structures (DRSs)

A new discourse starts a new DRS:

This DRS is meant to represent the meaning of an entire discourse.

When a new sentence is parsed (e.g. "A woman sorts"), the DRS is expanded:

x
$woman(x)$ $snort(x)$

- The x in the top of the box is a discourse referent.
- The expressions $woman(x)$ and $snort(x)$ are DRS-conditions

6.2. Processing subsequent sentences

Let's now interpret: "She collapses". We will do three things:

1. Add a new discourse referent
2. Add condition $collapse(y)$
3. Add a further condition $x = y$

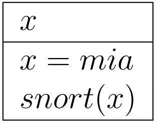
x, y
$woman(x)$
$snort(x)$
$collapse(y)$
$x = y$

Why did we do this?

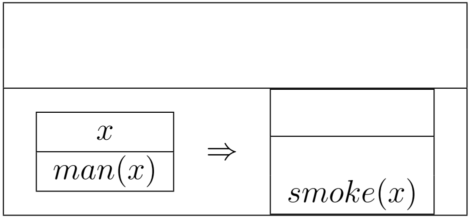
1. She is a pronoun
2. Pronouns introduce a discourse referent which get identified with an accessible discourse referent

6.3. Further Examples

1. Mia snorts.

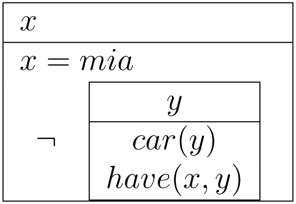


2. Every man smokes

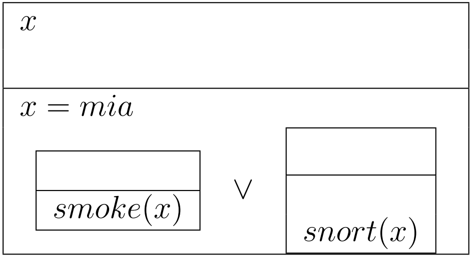


6.4. Further Example

1. Mia doesn't have a car.



2. Mia smokes or snorts.



1. If R is a relation symbol of arity n, and $\tau_1 \dots \tau_n$ are terms, then $R(\tau_1 \dots \tau_n)$ is a DRS-condition:
2. If τ_1 and τ_2 are terms then $\tau_1 = \tau_2$ is a DRS-condition
3. If B is a DRS, then $\neg B$ is a DRS-condition
4. If B_1 and B_2 are DRSs, then $B_1 \Rightarrow B_2$ and $B_1 \vee B_2$ are DRS-conditions.

6.6. Semantics of DRSs

Given that a DRS is supposed to be a picture, it seems natural to say that a DRS is satisfied in a model iff it is an accurate image of the information recorded inside the model. For instance:

For instance,

x, y
$woman(x)$ $boxer(y)$ $admire(x, y)$

is Satisfied in a model iff It is possible to associate x and y with entities of the model such that x is a woman, y is a boxer, and x and y stand in the "admire" relation.

6.7. Semantics of complex DRS

DRS-conditions

- A negated DRS will be satisfied if it is not possible to embed it in the model
- A disjunctive DRS-condition will be satisfied if at least one of the disjuncts can be embedded in the model
- An implicative DRS-condition will be satisfied if every way of embedding the antecedent DRS, gives rise to an embedding of the consequent DRS

6.8. Semantics of complex DRS-conditions

- A negated DRS will be satisfied if it is not possible to embed it in the model.
- A disjunctive DRS-condition will be satisfied if at least one of the disjuncts can be embedded in the model.
- An implicative DRS-condition will be satisfied if every way of embedding the antecedent DRS, gives rise to an embedding of the consequent DRS.

6.9. Accessibility in DRTs

- Resolving anaphoric pronouns is subject to accessibility constraints
- Accessibility is a geometric concept, defined in terms of the ways DRSs are nested into each other
- A DRS B_1 is accessible from DRS B_2 when B_1 equals B_2, or when B_1 subordinates B_2

6.10. Subordination

A DRS B_1 subordinates B_2 iff:

- B_1 immediately subordinates B_2
- There is a DRS B such that B_1 subordinates B and B subordinates B_2

B_1 immediately subordinates B_2 iff:

- B_1 contains a condition $\neg B_2$
- B_1 contains a condition $B_2 \vee B$ or $B \vee B_2$
- B_1 contains a condition $B_2 \Rightarrow B$
- $B_1 \Rightarrow B_2$ is a condition in some DRS B

6.11. The accessibility constraint

Suppose a pronoun has introduced a new discourse referent y into the universe of some DRS B.

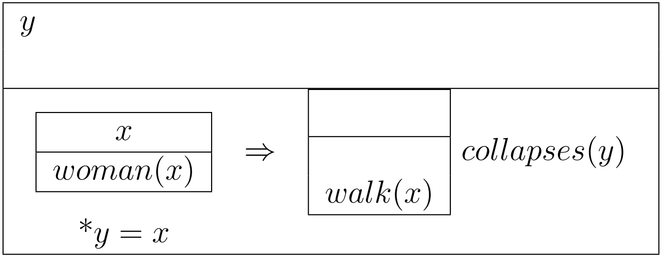
Then we are only free to add the condition $y = x$ to the conditions of B if x is declared in an accessible DRS from B

6.12. Example

1. A woman walks. She collapses.

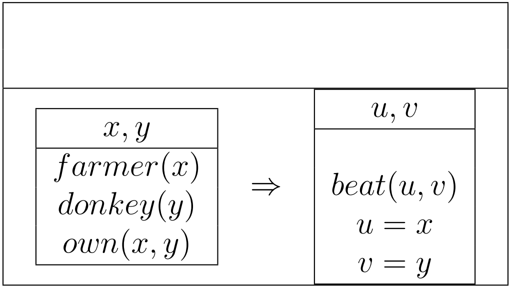
x, y
$woman(x)$
$snort(x)$
$collapse(y)$
$y = x$

2. Every woman walks. *She collapses.



6.13. Example

If a farmer owns a donkey, he beats it. Every farmer who owns a donkey beats it.



6.14. Interpreting DRSs

Once we have built DRS we can translate them into FOL.

Briefly, the discourse referents correspond to existential quantification. The ones in the antecedent of an implication correspond to universal quantification.

7. Anaphora Resolution

Example

Sophia Loren says she will always be grateful to Bono. The actress revealed that the U2 singer helped her calm down when she became scared by a thunderstorm while travelling on a plane.

- *she* ⇒ *Sophia Loren*
- *the actress* ⇒ *Sophia Loren*
- *the U2 singer* ⇒ *Bono*
- *her* ⇒ *Sophia Loren*
- *she* ⇒ *Sophia Loren*

7.1. Features

- Factors that affect the interpretation of anaphoric expressions:
  1. Morphological features (agreement)
  2. Syntactic information
  3. Salience
  4. Lexical and commonsense knowledge
- Distinction often made between CONSTRAINTS and PREFERENCES. E.g., gender and number are a strong constraint.
- PARALLELISM preferences Around 60% of pronouns occur in subject position; around 70% of those refer to antecedents in subject position.
- Factors that affect prominence, eg. Distance, Entities mentioned earlier in the sentence more prominent, etc.

7.2. History of ideas

1. Algorithms heavily based on (hand-coded) commonsense knowledge: Charniak 72, Winograd 74, Hobbs 1974, Wilks 1975

2. Syntax-based algorithms: Hobbs 1974

3. Salience-based algorithms: Brennan et al, Strube & Hahn, Tetreault

Today: ML, corpora annotation, evaluation.

7.3. First approaches: Charniak, Winograd, Wilks

- Heavy emphasis on inference
- Hand-coded
- No formal evaluation

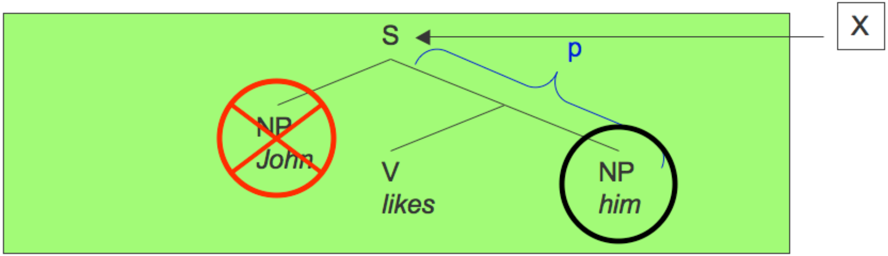
7.4. SHRDLU (Winograd)

- First example of HISTORY LIST algorithm
- Uses a combination of agreement features and semantic constraints
- Check all possibilities and assign a global score rather than simply find the first match
- Score incorporates syn component: entities in subj position higher score than entities in object position, in turn ranked more highly than entities in adjunct position
- Performance made more impressive by including solutions to a number of complex cases, such as reference to events (Why did you do it?) often ad hoc

7.5. Hobbs' "Naive Algorithm" (1974)

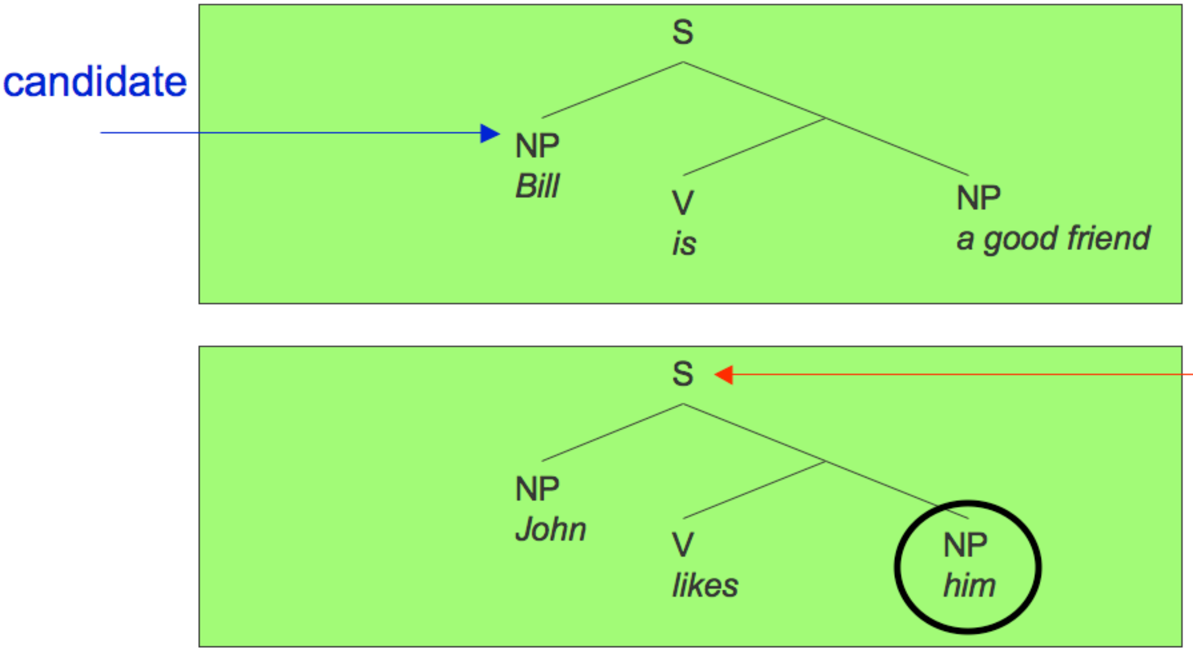
- The reference algorithm for PRONOUN resolution (until Soon et al it was the standard baseline)
- Interesting since Hobbs himself in the 1974 paper suggests that this algorithm is very limited (and proposes one based on semantics)
- The first anaphora resolution algorithm to have an (informal) evaluation Purely syntax based
- Works off surface parse tree
- Starting from the position of the pronoun in the surface tree,
  1. first go up the tree looking for an antecedent in the current sentence (left-to-right, breadth-first);
  2. then go to the previous sentence, again traversing left-to-right, breadth-first.
  3. And keep going back

- Steps 2 and 3 deal with intrasentential anaphora and incorporate basic syntactic constraints:



- Also: *John's portrait of him*

—


candidate
S
NP
Bill
V
is
NP
a good friend
S
NP
John
V
likes
NP
him

7.7. Evaluation

- The first anaphora resolution algorithm to be evaluated in a systematic manner, and still often used as baseline (hard to beat!)
- Hobbs, 1974:
  1. 300 pronouns from texts in three different styles (a fiction book, a non-fiction book, a magazine)
  2. Results: 88.3
  3. 132 ambiguous pronouns; 98 correctly resolved.
- Tetreault 2001 (no selectional restrictions; all pronouns)
  1. 1298 out of 1500 pronouns from 195 NYT articles (76.8
  2. 74.2
- Main limitations
  1. Reference to propositions excluded
  2. Plurals
  3. Reference to events

7.8. Salience-based Algorithm

- Common hypotheses:

  1. Entities in discourse model are RANKED by salience
  2. Salience gets continuously updated
  3. Most highly ranked entities are preferred antecedents

- Variants:

  1. DISCRETE theories (Sidner, Brennan et al, Strube & Hahn): 1-2 entities singled out
  2. CONTINUOUS theories (Alshawi, Lappin & Leass, Strube 1998, LRC): only ranking

7.9. MUC

- First big initiative in Information Extraction
- Produced first sizeable annotated data for coreference
- Developed first methods for evaluating systems

. . . and much more on the topic could be said.

8. Have fun!

- An online Inference system based on DRS: `DORIS`: http://www.coli.uni-sb.de/~bos/atp/doris.html
- An online game on anaphora: http://www.anawiki.org/anawikigame2/