Lecture 26: Dynamic Semantics

CS 1810
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Some slides based on those of Christina Unger

Coordination

- NP: John and Mary went to the store
  - John went to the store and Mary went to the store
- V: Mary danced and sang all night
  - Mary danced all night and Mary sang all night
- Adj: The ball was big and red
- VP: John kicked the ball and ran down the field
  - John kicked the ball and John ran down the field
- Ann baked and Betty ate all the cookies.

Meaning via Continuations

- What is context around conjunctive phrase?
  - Mary danced and sang all night
  - k = λx. Mary x all night
  - k (danced and sang) = k(danced) and k(sang)

  - intCON_CPS And = λk λm λn. k(m) ∧ k(n)
  - intCON_CPS Or = λk λm λn. k(m) ∨ k(n)

Still issues

- Chris and Betty met at the fair
  - Chris met at the fair ∧ Betty met at the fair????
- Different meaning of "and"
  - Individuals or group

Standard Approach

- Contrast continuations w/standard approach:
- Raise Boolean operators to function spaces
- Let f, g: A → Bool. Define ops on A → Bool
  - $(f \wedge g)(x) = f(x) \wedge g(x)$
  - $(f \vee g)(x) = f(x) \vee g(x)$
  - $(\neg f)(x) = \neg(f(x))$

Can go farther!

- Let BOOL :: = t | a → BOOL
  - where a is any type
  - So contains: (e→t) → (e→t), for example
- $\neg_t$, $\wedge_t$, and $\vee_t$ be usual ops on true,false
- Let s = t → u in Bool. Define recursively:
  - $\neg_s = \lambda P{:}s.\ \lambda x{:}t.\ \neg_u P(x)$
  - $\wedge_s = \lambda P{:}s.\ \lambda Q{:}s.\ \lambda x{:}t.\ P(x) \wedge_u Q(x)$
  - $\vee_s = \lambda P{:}s.\ \lambda Q{:}s.\ \lambda x{:}t.\ P(x) \vee_u Q(x)$

Example

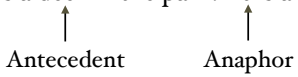
- intNP: NP → (e → t) → t
  - intNP (Conj np1 np2) = (intNP np1) $\wedge_{(e \to t) \to t}$ (intNP np2)
  - intNP (Disj np1 np2) = (intNP np1) $\vee_{(e \to t) \to t}$ (intNP np2)
- Similarly for adjectives, adverbs, etc.

Dynamic Semantics (Discourse Representation Theory)

From Sentences to Paragraphs!

Anaphora

- Anaphors are referentially dependent expressions.
  - Their interpretation is in some way determined by the interpretation of another expression, which is called the antecedent.
  - Prototypical example is referential pronoun
- There is a deer in the park. It is a statue.



Anaphora Resolution

- How do you figure out what anaphors refer to?
- *Cataphora (forward reference) too hard for us:* Because he refused to behave nicely, Mary walked away from James.

Come in many flavors

- Classify by:
  - Syntactic category (NP, VP, adverbs)
  - Type of antecedent (person or object, group, event)
  - Location of antecedent (same sentence or earlier, inferred from context or background)

Pronominal Anaphora

- Pronouns get most attention:
  - Personal pronouns: I like to visit new restaurants. **They** usually have interesting food.
  - Possessive pronouns: **Their** owners are trying hard to make **their** customers happy.
  - Reflexive pronouns: Sometimes they take **themselves** too seriously, however.

Noun Phrase Anaphora

- Noun phrases often refer back to previously mentioned items.
  - I ate at Otium last week. The restaurant was very busy.
- Special case: Epithets
  - *typically metaphoric - used for decorative or defamatory reasons*
  - This jewel of a restaurant is turning heads in LA.
  - I heard candidate X on TV yesterday. The liar really upset me.

Type of Antecedents

- Can be more complicated than just persons or objects
  - Last week we had an active shooter drill. **It** made **me** nervous.
  - I ride my bike every Sunday. **It** makes **me** happy!

Antecedent

- Antecedents are generally provided in the context.
  - linguistic context
    - explicitly mentioned in the previous discourse
  - physical context
    - persons, objects and events in range
  - knowledge context
    - can be inferred from the discourse and world knowledge

Antecedents in Extra-linguistic Context

- E.g., pronouns can be used without an explicitly mentioned antecedent if there is a salient entity given by the situation.
  - And? Do you like it?
  - Intuitively, the presence of the item and the attention it gets establishes it as a discourse entity.

Antecedents in Extra-linguistic Context

- Deictic pronouns refer to entities in the external world without having a linguistic antecedent. Their reference is often made clear by physical pointing and they are usually not counted as anaphors.
  - **You** will get to know **me** better.
  - Hand **that** to me. (*said while pointing*)

Inferred Antecedents

- Some antecedents are neither mentioned nor given by the situation, but have to be inferred from what was said, possibly together with world knowledge .
  - Mary and Sue met a long time ago. **They** are still friends.
  - I ate at Otium last week. **The waiter** was very helpful.
  - That car is a lemon. **The salesperson** lied to me.

Anaphoric Pronouns

- Recall: Interpretation of anaphor is determined by the interpretation of the antecedent.
- By the way the interpretation of a pronoun is determined by interpretation of the antecedent, distinguish at least three kinds of anaphoric pronouns:
  - referential pronouns
  - bound variable pronouns
  - E-type and lazy pronouns

Referential pronouns

- Referential pronouns refer to some entity in the external world, either directly or via coreference with its antecedent.
  - The girl is enjoying her meal. **She** seems to savor every bite.

Identity of reference or of sense

- Anaphor can refer to the *reference* or the *sense* of the antecedent.
- The president stepped off the plane. She waved to the crowd.
- The president is elected every four years. She came in way ahead among minority voters.

Bound Variable Pronouns

- Bound variable pronouns do not refer to fixed entities in the world. They take a range of values, which depends on some quantificational expression.
  - Each candidate claimed he would be best.
  - No candidate could imagine he would lose.
  - One candidate would win. She would have quite a celebration!
- *BVP's appear in different ways in different languages: personal pronouns, reflexive pronouns, etc.*

E-Type Pronouns

- Hard to model formally. See donkey sentences:
  - Every farmer who owns a donkey, feeds it.
- Existential or universal quantifier "a"???
  - Nested universal?

Translations

- Every farmer who owns a donkey is rich.
  - $\forall x(\text{farmer}(x) \wedge \exists y(\text{donkey}(y) \wedge \text{owns}(x,y)) \rightarrow \text{rich}(x))$
- Every farmer who owns a donkey, feeds it.
  - $\forall x(\text{farmer}(x) \wedge \exists y(\text{donkey}(y) \wedge \text{owns}(x,y)) \rightarrow \text{feeds}(x,\mathbf{y}))$
    - *last y is free!!*
  - $\forall x\exists y(\text{farmer}(x) \wedge \text{donkey}(y) \wedge \text{owns}(x,y)) \rightarrow \text{feeds}(x,y))$
    - *Clearly wrong as always true if there is any non-donkey.*
  - $\forall x\forall y(\text{farmer}(x) \wedge \text{donkey}(y) \wedge \text{owns}(x,y)) \rightarrow \text{feeds}(x,y))$
    - *Seems fine, but destroyed structure of sentence. "a" is* $\forall$*?*

Lazy Pronouns

- A pronoun is called lazy, when it seems to function as a shorthand for a repetition of its antecedent. So it is a device for repeating an occurrence of a linguistic form rather than for referring back to its reference.
  - The farmer who feeds his donkey is much nicer than the farmer who beats him.

Non-Anaphoric Pronouns

- Not all occurrences of "it" are anaphoric. These are called pleonastic, and don't refer to anything!
  - It's been raining for two weeks.
  - It is not as late as I thought.
  - There was wild dancing.
  - It's a long way to Tokyo.
  - It is forbidden to smoke here.

Attacking the Problem!

Interpreting Pronouns

- There is a deer in the park. It is a statue.
  - $\exists x.((\text{deer } x) \wedge (\text{inPark } x) \wedge (\text{statue } x))$
- But two separate sentences:
  - $\exists x.((\text{deer } x) \wedge (\text{inPark } x))$
  - $(\text{statue } x)$
- Problem: Want to keep asserting things about x, but subsequent occurrences of x are outside of the scope of $\exists$.

Key Insights

- Sentences are not islands but are embedded in a discourse and often related to other sentences in that discourse.
- Discourses are about entities, which are introduced and can then be referred back to.

Dynamic Approach

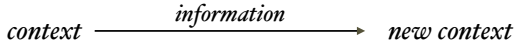
- Utterances play two roles:
  - They convey information about the world. (truth conditions)
  - They change the context (e.g. introduce new referents) in which subsequent utterances will be interpreted. (context change potential)
- Predicate logical representations handle the truth-conditional dimension of meaning well, but the context dimension is missing.

Dynamic Approach

- Static semantics:
  - Sentences express truth-conditions.
- Dynamic semantics:
  - Sentences are instructions for updating a discourse representation.
  - Dynamic semantics investigates aspects of interpretation that are beyond mere truth-conditions, mainly how the interpretation of natural language expressions depends on the context and also how it changes that context.

Meaning as Context Change Potential

- A context (or: information state) comprises the entities we are talking about and what we have said about these entities.
- Emphasis is in the growth of information in time, i.e. not only on the result of interpretation but also on the interpretation process.
- Pieces of text or discourse are viewed as instructions to update an existing context with new information.



Dynamic Semantic Theories

- Discourse Representation Theory (Hans Kamp, 1981)
- File Change Semantics (Irene Heim, 1982)
- Dynamic Predicate Logic (Jeroen Groenendijk & Martin Stokhof, 1991)

Context

- Hans found a unicorn. **He** photographed **it** before **it** could run away from **him**. **He** showed Mary **the photo**, but **she** thought **he** was playing **a joke**.
- Add context parameter (set of referents) to each denotation and pass it around during interpretation process.
- Names and indefinite NP's add referents to context, pronouns and definite NP's pick up referents from context.

Adding Context

- What about quantifiers?
  - Each unicorn thinks **it** is the only one of **its** kind.
  - Each unicorn grazes. **It** is bored???
  - John didn't eat lunch. **It** was good.????

Adding Context

- Context needs more structure
  - DRT incorporates structure in discourse representations.
- Developed by Kamp in early 80s

Interpretation in Context

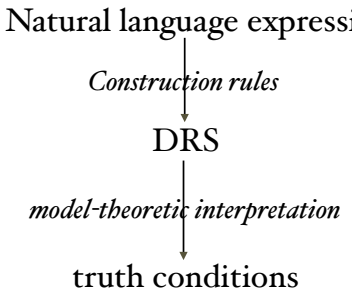
- Each sentence of a discourse is interpreted in the context of the preceding sentences.
- Context updated with the contribution of the sentence, yielding a new context in which subsequent sentences are interpreted.
- This update often involves connecting elements of the sentence with elements from the context (e.g. antecedents for anaphors).

Content and Context

- Same structure serves simultaneously as content and as context – two concepts that are kept separate in Montague semantics.
- Common idea in the psychology of language:
  - A hearer builds up a mental representation of the discourse as it unfolds, and every incoming sentence prompts additions to that representation.
- DRT uses this idea as starting point for semantic theory:
  - The interpretation process builds mental representations called Discourse Representation Structures (DRS).

Semantics in DRT

- The level of semantic representations is essential again. (Recall that it was completely dispensable in Montague semantics.)



Ingredients

- a formal definition of the representation language
  - a recursive definition of well-formed DRSs
  - a model-theoretic semantics for those DRSs
- a construction procedure for updating an existing DRS when a new sentence is added to the discourse

Discourse Representation Structures

- A DRS consists of two parts:
  - a set of referent markers (or: discourse referents) for the entities that a discourse is about
  - a set of conditions (formulas)
- Example: The boy ate dinner.

x, y
boy(x) dinner(y) ate(x,y)

Discourse Representation Structures

- Example: The boy ate dinner. It was good.

x, y, z
boy(x) dinner(y) ate(x,y) good(z) y = z

Referent Markers

- The referent markers in the universe of a DRS are interpreted existentially.
- All referent markers in the universe of a context DRS are available as antecedents to pronouns and other anaphoric expressions that are interpreted within this context.
- The interpretation of a sentence S in the context provided by a DRS D results in a new DRS D′, which captures the content represented by D together with the content of S, as interpreted with respect to D.

Like Programs

- Introduction of new variable results in allocation of new space
- New variable can be used in later statements.

Questions?