6.863J Natural Language Processing
Lecture 20: the meaning of it all, #6

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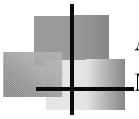
The Menu Bar

- Administrivia:
  - Lab 4(a&b) out today – last lab before final project – due April 28

Agenda:

How to use language: discourse structure & anaphora

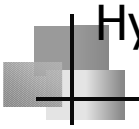
discourse representation structure, presuppositions, and language etiquette



ABSTRACT – CONCRETE
NONLIVING – LIVING

EDIBLE – INEDIBLE
IMMOBILE – MOBILE
ANIMATE – INANIMATE
NONHUMAN – HUMAN
MALE – FEMALE

Hypernym: All X, car x implies vehicle x
All x, concrete x implies not abstract x



Hypernyms and Wordnet

Discourse

- Mia is a woman. She loves Vincent
- A man snorts. He collapses.
- Problems: complex post-processing & counter-intuitive readings
- Biggest problem: discourse is not just set of FOL sentences, glued together…

What is the glue?

- Discourse anaphora
- John bought a book. It is a best-seller
- John bought a Porsche or a Prius. It is a best-seller
- John did not buy a Porsche. It is a best-seller
- John did not buy a five dollar shake. Vincent tasted it

More examples

- Butch threw a vase at the wall
- It broke
- Butch walks into his modest kitchen. He opens the refrigerator. He takes out a milk and drinks it.
- Butch walks into his modest kitchen. He opens the refrigerator. He takes out a glass of iced tree and drinks it.

Discourse representation theory (DRT)

- Semantic framework w/ a language to describe discourse
- Translate discourse to FO logic
- Compatible with lambda calculus approach

DRT overview

- Uses language based on box-like structures called DRSs (discourse representation structures)
- Intuition: DRSs are pictures
- Another (nonrepresentational) view: DRSs are programs

And with this…

- We can do most 'common' anaphora…
- But wait, there's more…

Why doesn't FOL logic work for discourse?

- Discourse is not simply the conjunction of first-order representations of individual sentences
- Why?
- Try this discourse: Mia is a cat. She loves Vincent.
- First sentence: cat(mia)
- Suppose free variable like pronoun, eg, love(x, vincent)
- Conjunction is: cat(mia)$\wedge$ love(x, vincent)
- "she" is an anaphoric pronouns – refers back to mia

What to do?

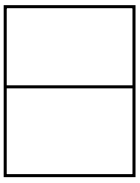
- Answer 1: replace x with 'mia' – a post-processing step
  - But this won't work – breaks down for:
    A cat sneezes. She collapses.
  - First-order approach: $\exists$z(cat(z)$\wedge$sneeze(z) $\wedge$ collapse(x))
  - Replace free variable x with z
  - This is truth-conditionally correct, but…
  - Doesn't tell us the context in which subsquent utterances will be interpreted
  - Instead of post-processing context conditions back in, make representation contain them at the start

DRT

- Represent context
- Allow access to truth-conditional aspects

Context change potential

- When we utter 'a man snorts' we don't simply make a claim about the world, we change the context in which subsequent utterances will be interpreted (hmm, like a frame….)
- Start a new discourse with the empty box



What's different about this?

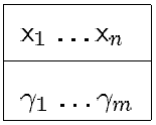
- Inter-sentential perspective from the start
- Top compartment holds discourse referents (note: this are not quite like variables…!)
- Bottom compartment holds conditions
- Top is like domain of a little model – the discourse model

Anaphoric pronoun

- Introduces new discourse referent (eg, "y")
- Must be identified with a (previous) accessible discourse referent
- In the simple case, x=y

Defining discourse representation languages (DRS)

1. If x_1 , …, x_n are discourse referents ($n \geq 0$) and γ_1 , … , γ_m ($m \geq 0$) are conditions then



is a DRS

This defines the "box" – in simplest case, the empty universe with no conditions

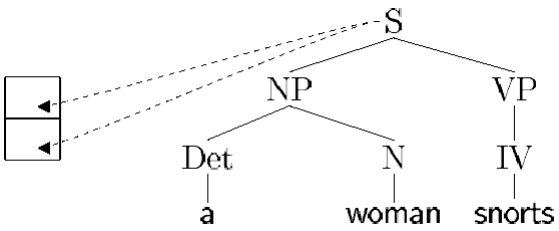
A term is either a constant or a discourse referent

Defining discourse representation languages (DRS)

2. If R is a relation symbol of arity *n* and t_1 , …, t_n are some terms, then R(t_1 , …, t_n) is a condition
3. If t_1 and t_2 are terms, then $t_1 = t_2$ is a condition
4. If B is a DRS, then $\neg$B is a condition
5. If B_1 and B_2 are DRSs, then $B_1 \vee B_2$ is a condition
6. If B_1 and B_2 are DRSs, then $B_1 \Rightarrow B_2$ is a condition
7. Nothing else is a DRS or a condition

The standard (top down) construction algorithm

- Start w/ parse tree & feed info from initial sentence into a box, top-down, left-right
- Example: a woman snorts
- Step 1



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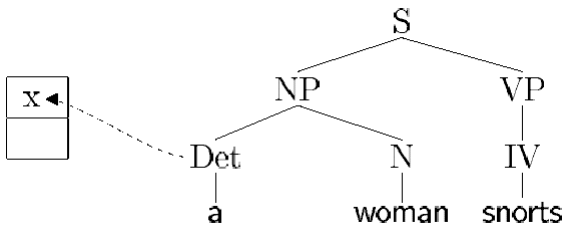
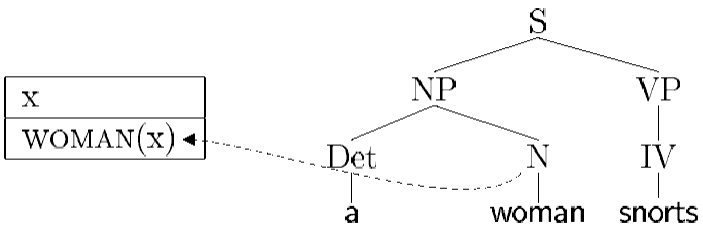
Step 2 a…

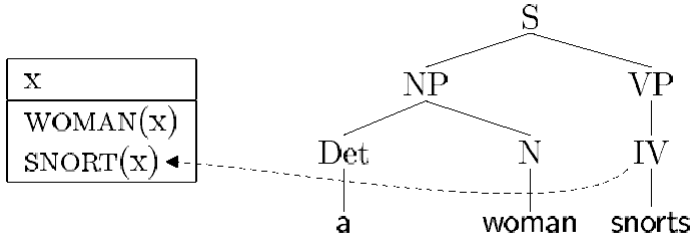


What conditions attach to this discourse referent?
Move to N node

Step 3 '…woman…'

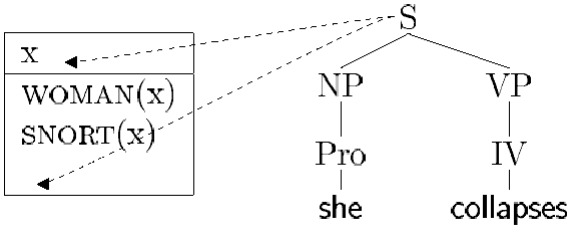


Step 4 …snorts…

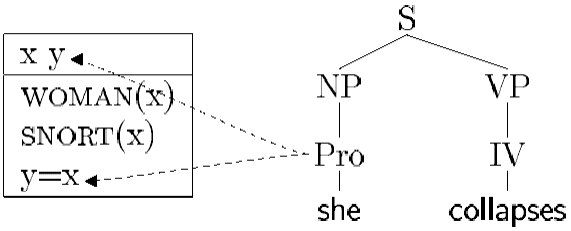


2nd sentence

Add info straight into box for the first…



Add new discourse referent…



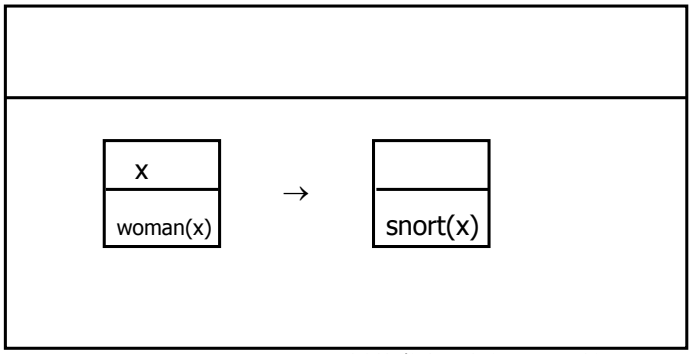
(note that x is accessible to y
What about <u>every</u> woman snorts. She collapses)

Examples

- A woman snorts. She collapses
- x,y belong to the <u>same</u> universe, x is accessible to y
- Every woman snorts. ? She collapses
- In this case, we have:

Calculating accessibilty

- Every woman snorts.



Calculating accessibilty

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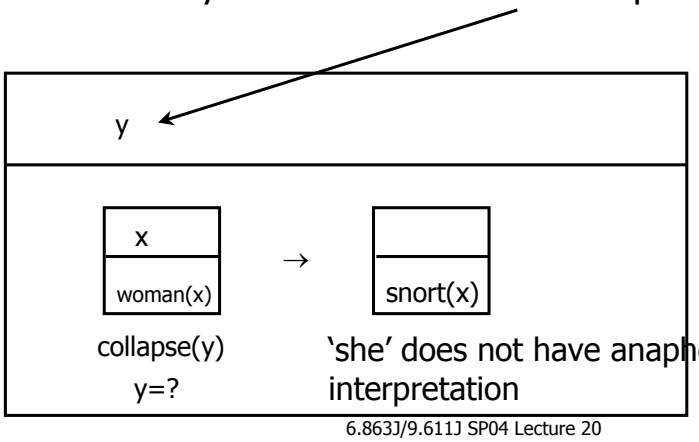


Pronouns, anaphora, accessibility

- John bought a book. It is a best-seller
- John bought a Porsche or a Prius. It is a best-seller
- John did not buy a Porsche. It is a best-seller
- John did not buy a five dollar shake. Vincent tasted it

Accessibility – the major constraint on anaphora

- ~~DRS B_1 is accessible from DRS B_2 iff $B_1 = B_2$ or B_1 subordinates B_2~~
- B_1 subordinates B_2 iff
  1. B_1 immediately subordinates B_2 or
  2. There is some DRS B s.t. B_1 subordinates B and B subordinates B_2
- B_1 immediately subordinates B_2 iff
  1. B_1 contains a condition of the form $\neg B_2$; or
  2. B_1 contains a condition of the form $B_2 \vee B$ or $B \vee B_2$ for some DRS B; or
  3. B_1 contains a condition of the form $B_2 \Rightarrow B$; or
  4. $B_1 \Rightarrow B_2$ is a condition in some DRS B

Pronoun accessibility

- 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 condition set of B if x is accessible from y

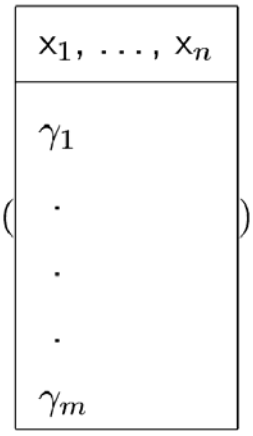
DRSs and FOL (with equality)

- Can map any DRS to FOL statements
- Can do the reverse – FOL to DRS
- Method: by construction, piece by piece

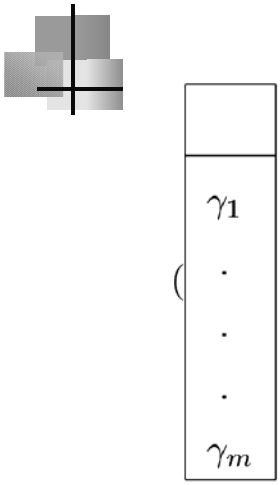
Lost in translation: DRS to FOL

- Empty boxes
- Basic conditions & atomic formulas
- Complex conditions (negations and disjunctions)
- Implications
  - When antecedent is empty
  - When it is not

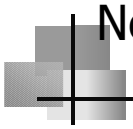
Non-empty boxes - translation



$$(\quad)^t \quad = \quad \exists x_1 \cdots \exists x_n((\gamma_1)^t \wedge \cdots \wedge (\gamma_m)^t$$



$$(\quad \Rightarrow \mathrm{K})^t \quad = \quad ((\gamma_1)^t \wedge \cdots \wedge (\gamma_m)^t) \rightarrow \mathrm{K}^t$$

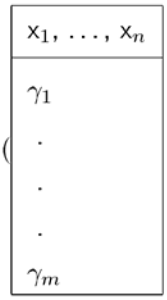


Negations and disjunctions

$$(\neg \mathrm{K})^t \quad = \quad \neg(\mathrm{K})^t$$

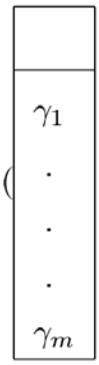
$$(\mathrm{K}_1 \vee \mathrm{K}_2)^t \quad = \quad (\mathrm{K}_1)^t \vee (\mathrm{K}_2)^t$$

Translating $\Rightarrow$ nonempty universe



$$(\quad \Rightarrow \mathrm{K})^t \quad = \quad \forall x_1 \cdots \forall x_n (((\gamma_1)^t \wedge \cdots \wedge (\gamma_m)^t) \rightarrow (\mathrm{K})^t)$$

Antecedent has empty universe

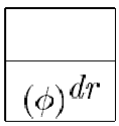


$$(\quad \Rightarrow \mathrm{K})^t \quad = \quad ((\gamma_1)^t \wedge \cdots \wedge (\gamma_m)^t) \rightarrow \mathrm{K}^t$$

Translating DRSs to FOL (with equality)

- Empty DRS is just T
- No conditions (empty bottom box) is $\exists x_1 \ldots \exists x_n\, T$
- Empty universe $(\gamma_1)^t \wedge \ldots \wedge (\gamma_n)^t$

From FOL to DRS



Atomic formulas

Discourse Referents
Conditions $(\tau_1 = \tau_2)^{dr}$ *Conditions*

Discourse Referents
Conditions $\tau_1 = \tau_2$ *Conditions*

Negation conversion

Discourse Referents
Conditions $(\neg\phi)^{dr}$ *Conditions*

Discourse Referents
Conditions ¬ [ ] / $(\phi)^{dr}$ *Conditions*

Existential conversion

Discourse Referents
Conditions $(\exists x \phi)^{dr}$ *Conditions*

x, *Discourse Referents*
Conditions $(\phi)^{dr}$ *Conditions*

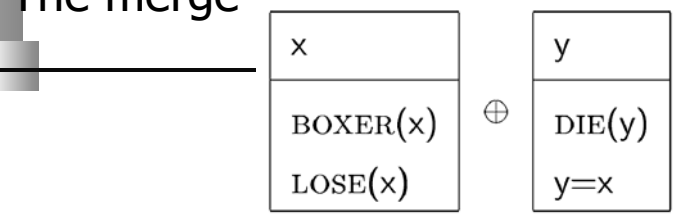
DRSs and lambda calculus

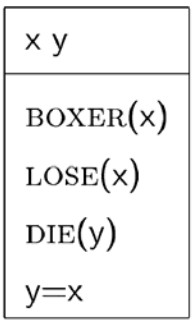
- Use lambdas to represent missing info in DRSs, rather than first-order formulas
- Add merge operator
- Use this to state precisely what it means to fold in info from each sentence in turn
- Also needed for lexical entries

Building DRSs with lambda

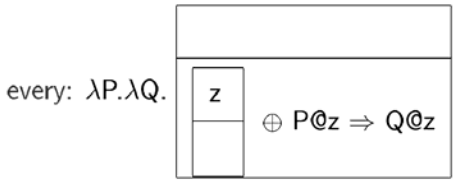
- Use DRS language, add λ, application operator @, and a new operator, merge, $\oplus$
- Result: λ–DRT
- Let's see…

The merge





DRS and lambda comparison - determiners



Every: λP. λQ. ∀z(P@z→Q@z)

"every"

- The abstracted variable P marks the missing restriction info; while Q marks the missing nuclear scope
- The quantificational force obtains by using a combination of the box and implicational sign, analogous to the universal quantifier and the implicational arrow in the other

Lexical items: Nouns, and Intrans V

boxer: $\lambda y.$ | | BOXER(y) |

woman: $\lambda y.$ | | WOMAN(y) |

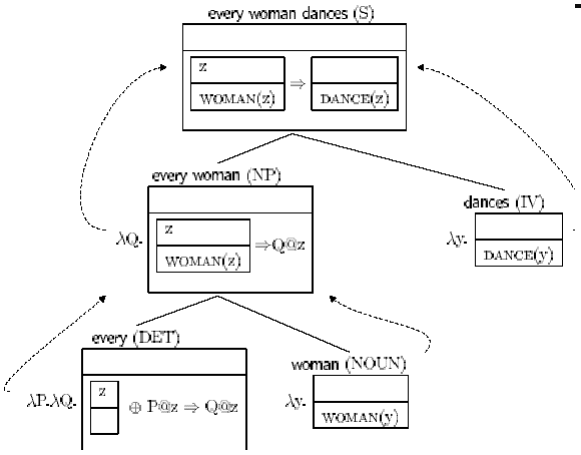
dances: $\lambda y.$ | | DANCE(y) |

Proper names, Determiners

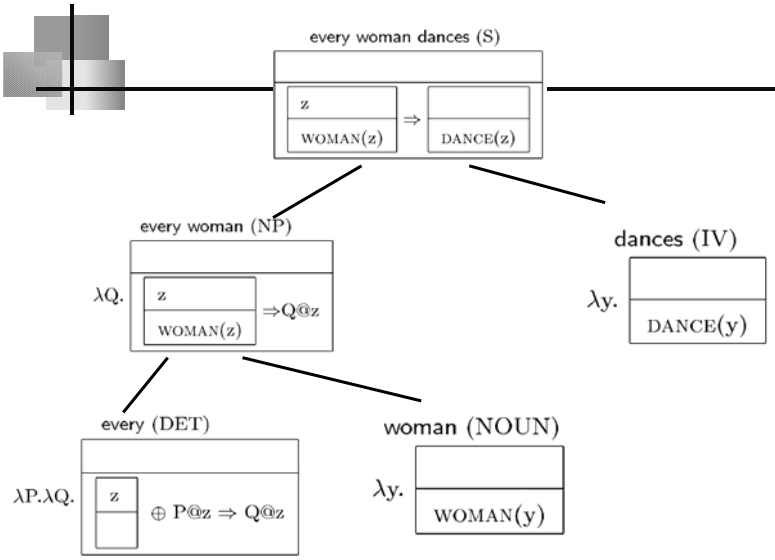
Mia: $\lambda P.$ | x | x = MIA | $\oplus$ P@x

a: $\lambda P.\lambda Q.$ | z | | $\oplus$ P@z $\oplus$ Q@z

Every woman dances



Every woman dances

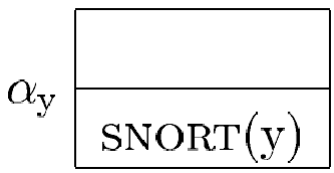


Examples

- Mia didn't order a five dollar shake. ?Vincent tasted it
- Why?
- Are these the only constraints?
- Butch threw a vase at the wall
- It broke
- Butch walks into his modest kitchen. He opens the refrigerator. He takes out a milk and drinks it.
- Cf: 'cup of coffee' – in "drink a cup of coffee"

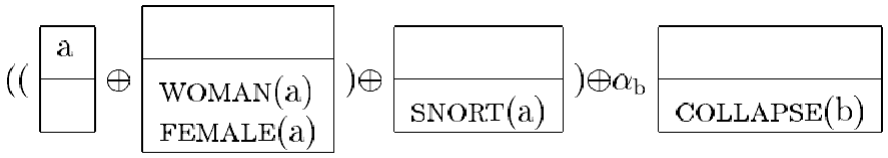
Anaphoric pronouns

- She snorts
- Put this into box notation with an 'alpha' (for 'anaphoric' as follows:



Like a lambda…

Discourse: a woman snorts. She collapses



Must get rid of merges and the alphas to get a pure DRS – this is called resolution

Anaphora Resolution

- Input: a stack of DRSs; the first is the DRS under examination, the others all subordinating it
- Output: a copy of the input, but with the merges and pronouns resolved
- Pronoun resolution: Take a DRS from the accessible list and find a unification of the alpha-bound variable and an accessible discourse referent

Proper binding constraint

- Vincent enters the restaurant and Jules watches him

Pronouns, anaphora, accessibility

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- John bought a Porsche or a Prius. It is a best-seller
- John did not buy a Porsche. It is a best-seller
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We need more constraint…

- Too many anaphora possibilities
- So we add notion of focus

Presuppositions

- Jody has no cat. ? Jody loves her cat
- Jody has no cat ? Jody does not love her cat

- For these to be OK, presupposed that Jody has a cat…
- Is there a systematic way to compute what is presupposed?

Presupposition is not entailment…

- The couple that won the dance contest was pleased
- The couple that did not win the dance contest was pleased
- Triggered by 'the' ?

Three problems with presuppositions

- The binding problem
- The projection problem
- The accommodation problem

Binding

- A boxer nearly escaped from his apartment

- What is the presupposition?
- Someone has an apartment
- In particular, it's possible: the boxer we are talking about has an apartment

Projection problem

- Mia's cat is at the vet (presupposes that Mia has a cat)
- If Mia has a cat, then her cat is at the vet (does not presuppose that Mia has a cat)

- Answer: presuppositions introduce new 'anaphoric' DRSs (not just new discourse referents, like pronouns)

Presuppositions and DRT

- Presuppositions are essentially very rich pronouns
- Like ordinary pronouns – use notion of accessibliity
- But – they have more descriptive content
- So – they introduce new DRSs