Ling130 – Lecture Notes for 3/26/10

Quick Review

- On Tuesday, we started to use DRT to deal with the anaphora problem
- We wanted a compositional treatment of discourse, but DRT isn't really compositional
  - Ideally, the compositional interpretation and the FOL interpretation should have the same truth values
    - *A man walks in the park. He whistles.*
    - FOL: $\exists x[man(x) \wedge walk(x) \wedge whistle(x)]$
    - Compositional FOL: $\exists x[man(x) \wedge walk(x)] \wedge whistle(x)$
    - DRT: *[x][man(x), walk(x), whistle(x)]*
    - The DRT version works, but is basically no different than the FOL version.
- DPL attempts to deal with the compositional version directly by changing how the logical connectives are interpreted.

The Dynamic View on Meaning

- Traditionally, we think of the meaning of a sentence in terms of truth conditions.
- Dynamic treatments of semantics do something different.
  - The meaning of a sentence lies in the way it changes the representation of the information of the interpreter.
  - Think of everything you know at the time you hear an utterance as an information state. When a quantifier or an indefinite description come along, that changes your

information state because you now have a new referent that you might refer to later.

  - *Meaning=state transition*
    - An utterance of a sentence brings us from a certain state of information to another one

- From now on, we're going to be dealing with interpretations.
  - In FOL, an interpretation is a model that assigns sets to predicates and so on.
  - In DPL, an interpretation is a set of ordered pairs of assignments, or the set of all its possible input-output pairs (Think of a sentence like a computer program. The input is your current information state. The output is your information state after hearing the sentence.)
    - A pair $<g,h>$ is in the interpretation of a program π, if when π is executed in state g, a possible resulting state is h

Dynamic Predicate Logic

- *Vocabulary of DPL*
  - n-place predicates, individual constants, and variables
  - The interpretation function F does the usual thing (assigns individuals to constants and n-tuples of individuals to n-place predicates)
  - Assignments, denoted by g, h, etc. are total functions from the set of variables to the domain D
  - $h[x]g$ means that assignment h differs from g at most with respect to the value it assigns to x
  - As with program interpretation in DL, the interpretation of a DPL sentence is a set of ordered pairs

- <*g,h*> is in the interpretation of a formula ϕ iff when ϕ is evaluated with respect to *g*, *h* is a possible outcome of the evaluation procedure

- Problem 1: Cross-sentential Anaphora ($\exists xPx \wedge Qx$)
  - **Dynamic Existential Quantification**
    - $[\![\exists xPx]\!] = \{\langle g,h\rangle | h[x]g \ \& \ h(x) \in F(P)\}$
      - An assignment *g* is the interpretation of $\exists xPx$ iff there is some assignment *h* which differs from *g* at most with respect to the value it assigns to *x*, and which is in the interpretation of *Px*
      - *John walks.* ➔ *Wj* ➔ $\exists xWx$
        - $[\![\exists xWx]\!] = \{\langle g,h\rangle | h[x]g \ \& \ h(x) \in F(W)\}$
        - *g:∅, h:{j}*
    - This doesn't account for the general case of $\exists x\phi$ yet, but this does:
      - $[\![\exists x\phi]\!] = \{\langle g,h\rangle | \exists k : k[x]g \ \& \ \langle k,h\rangle \in [\![\phi]\!]\}$
      - This version allows for ϕ to be anything. Anytime, $[\![\ \ ]\!]$ is used, this means to continue interpreting what's inside the brackets dynamically.
  - **Dynamic Conjunction**
    - We need to be able to pass variables from the first conjunct to the second one, and these values should also be left available for future conjuncts
      - $[\![\phi \wedge \psi]\!] = \{\langle g,h\rangle | \exists k : \langle g,k\rangle \in [\![\phi]\!] \ \& \ \langle k,h\rangle \in [\![\psi]\!]\}$
    - Note that conjunction (and existential quantification) are internally dynamic because it can pass variable bindings from the left conjunct to the right

- It (they) is also externally dynamic because it can keep passing on bindings to future conjuncts

- $[\![\exists xPx \wedge Qx]\!]$
  - We can almost do this, but we need to know the interpretation of **atomic formulas**:
    - $[\![Rt_1,\ldots,t_n]\!] = \{\langle g,h\rangle \mid h = g \ \& \ \langle [\![t_1]\!]_h,\ldots,[\![t_n]\!]_h\rangle \in F(R)\}$
    - Notice that the assignments g and h are equivalent in this interpretation
      - This characteristic of a <u>test</u>. These formulas have no dynamic effects on their own
      - Tests let assignments that satisfy them through (the second part of the interpretation) and block those that don't
      - We'll see many more examples of tests in the rest of DPL semantics
- Now, we can work out the interpretation of $[\![\exists xPx \wedge Qx]\!] =$
  - $\{\langle g,h\rangle \mid \exists k : \langle g,k\rangle \in [\![\exists xPx]\!] \ \& \ \langle k,h\rangle \in [\![Qx]\!]\} =$
    - Begin with the main connective (conjunction)
  - $\{\langle g,h\rangle \mid \exists k : k[x]g \ \& \ k(x) \in F(P) \ \& \ h = k \ \& \ h(x) \in F(Q)\} =$
    - Give the interpretation for *∃xPx* and use the atomic formula rule on the resulting *Px* and *Qx*
  - $\{\langle g,h\rangle \mid h[x]g \ \& \ h(x) \in F(P) \ \& \ h(x) \in F(Q)\}$
    - Finally, we get rid of instances of the assignment *k* by replacing it with h

- Problem 2: Donkey Anaphora (*∀xPx→Qx*)
  - **Dynamic Implication**
    - Implication passes values from the antecedent to the consequent, so it is internally dynamic

- However, implication, in general, doesn't pass values to later sentences, so it is not externally dynamic
  - We will see a counter example to this claim, but for now, we'll just go with it ☺
- Since implication is not externally dynamic, it functions as a test in DPL:
  - $[\![\phi \to \psi]\!] = \{\langle g,h\rangle | h = g \;\&\; \forall k : \langle h,k\rangle \in [\![\phi]\!] \Rightarrow \exists j : \langle k,j\rangle \in [\![\psi]\!]\}$
    - The interpretation of $\phi \to \psi$ accepts an assignment *g* iff every possible output of ϕ with respect to *g* leads to a successful interpretation of ψ, and it rejects *g* otherwise
  - $$[\![\exists xPx \to Qx]\!] =$$ $$\{\langle g,h\rangle | h = g \;\&\; \forall k : \langle h,k\rangle \in [\![\exists xPx]\!] \Rightarrow \exists j : \langle k,j\rangle \in [\![Qx]\!]\} =$$ $$\{\langle g,g\rangle | \forall k : \langle g,k\rangle \in [\![\exists xPx]\!] \Rightarrow \exists j : \langle k,j\rangle \in [\![Qx]\!]\} =$$ $$\{\langle g,g\rangle | \forall k : k[x]g \;\&\; k(x) \in F(P) \Rightarrow k(x) \in F(Q)\}$$
- **Dynamic Universal Quantification**
  - Externally static, so functions as a test:
    - $[\![\forall x\phi]\!] = \{\langle g,h\rangle | h = g \;\&\; \forall k : k[x]h \Rightarrow \exists m : \langle k,m\rangle \in [\![\phi]\!]\}$
  - Big Example (*Every farmer who owns a donkey beats it.*): (Really hard, we won't ask you to do anything like this!)

$$[\![\forall x[[Px \wedge \exists y[Qy \wedge Rxy]] \to Sxy]]\!] =$$

$$1. \left\{\langle g,h\rangle \middle| h = g \;\&\; \forall k : k[x]h \Rightarrow \exists m : \langle k,m\rangle \in [\![[Px \wedge \exists y[Qy \wedge Rxy]] \to Sxy]\!]\right\} =$$

$$2. \left\{\langle g,g\rangle \middle| \forall k : k[x]g \Rightarrow \left(\forall j : \langle k,j\rangle \in [\![Px \wedge \exists y[Qy \wedge Rxy]]\!] \Rightarrow \exists z : \langle j,z\rangle \in [\![Sxy]\!]\right)\right\} =$$

$$3. \left\{\langle g,g\rangle \middle| \forall k : k[x]g \;\&\; k(x) \in F(P) \Rightarrow \left(\forall j : j[y]k \;\&\; j(y) \in F(Q) \;\&\; \langle j(x), j(y)\rangle \in F(R) \Rightarrow \langle j(x), j(y)\rangle \in F(S)\right)\right\} =$$

$$4. \left\{\langle g,g\rangle \middle| \forall h : h[x,y]g \;\&\; h(x) \in F(P) \;\&\; h(y) \in F(Q) \;\&\; \langle h(x),h(y)\rangle \in F(R) \Rightarrow \langle h(x),h(y)\rangle \in F(S)\right\}$$

Line 1: Apply the universal quantification rule

Line 2: Replace occurrences of h with g and apply the implication rule

Line 3: Apply the atomic formula rule along with the conjunction and existential quantification rules

Line 4: Simplify by removing quantifiers where possible

- Remaining Connectives
  - **Dynamic Negation**
    - $[\![\neg\phi]\!] = \{\langle g,h\rangle | h = g \,\&\, \neg\exists k : \langle h,k\rangle \in [\![\phi]\!]\}$
    - Big Example #2:

$$[\![\neg\exists xPx \wedge Qx]\!] =$$
$$1.\{\langle g,h\rangle | \exists k : \langle g,k\rangle \in [\![\neg\exists xPx]\!] \,\&\, \langle k,h\rangle \in [\![Qx]\!]\} =$$
$$2.\{\langle g,h\rangle | \exists k : \langle g,k\rangle \in [\![\neg\exists xPx]\!] \,\&\, h = k \,\&\, h(x) \in F(Q)\} =$$
$$3.\{\langle g,h\rangle | \langle g,h\rangle \in [\![\neg\exists xPx]\!] \,\&\, h(x) \in F(Q)\} =$$
$$4.\{\langle g,h\rangle | h = g \,\&\, \neg\exists k : \langle h,k\rangle \in \{\langle g,h\rangle | h[x]g \,\&\, h(x) \in F(P)\} \,\&\, h(x) \in F(Q)\} =$$
$$5.\{\langle g,g\rangle | \neg\exists k : k[x]g \,\&\, k(x) \in F(P) \,\&\, g(x) \in F(Q)\}$$

Line 1: Apply conjunction rule

Line 2: Apply the atomic formula rule to $\langle k,h\rangle \in [\![Qx]\!]$

Line 3: Replace occurrences of k with h

Line 4: Apply the negation rule, leave the second conjunct alone, and, while you're at it, apply the existential and atomic formula rules to that conjunct

Line 5: Replace occurrences of h with g and apply the atomic formula rule

- **Dynamic Disjunction**
  - $[\![\phi \vee \psi]\!] = \{\langle g,h\rangle | h = g \,\&\, \exists k : \langle h,k\rangle \in [\![\phi]\!] \vee \langle h,k\rangle \in [\![\psi]\!]\}$
  - Disjunction is unique because it is both externally and internally static

- Summary
  - Most logical constants in DPL are interpreted as tests (their interpretations include *h=g*). The exceptions are conjunction and existential quantification because they are externally dynamic (they force a dynamic interpretation beyond their own scope).

❖ Concluding Remarks

- Recall the overall goal: Develop a compositional, non-representation semantics of discourse that enables us to marry the compositional framework of Montague grammar to a dynamic outlook on meaning
  - Empirically, DPL is like Discourse Representation Theory (DRT)
    - The interpretation of a DRT structure is dynamic, but this only comes out in the interpretation of implication
    - So, DRT gets us closer to the dynamic interpretation of anaphora that we want, but isn't compositional
  - Methodologically, DPL is like Montague Grammar because it incorporates compositionality
- So, what's missing?
  - DPL is restricted to an extensional first-order system, but Montague Grammar makes use of intensional higher order logic

- The authors present a solution to this called ‘Dynamic Montague Grammar’ in another 1990 paper

- DPL has some things in common with Discourse Representation Theory that are controversial
  - There are examples that show that universal quantification, implication, disjunction, and negation are, in some contexts, both internally and externally dynamic
    - “If a client turns up, you treat him politely. You offer him a cup of coffee and ask him to wait.”
    - “Every player chooses a pawn. He puts it on square one.”
  - The authors solution to this problem is to provide a paraphrase of the discourse that gets around the non-dynamic aspects
    - “If a client turns up, you treat him politely, you offer him a cup of coffee, and ask him to wait.”
      - Here the second part of the discourse is folded into the consequent of the conditional to take advantage of the internally dynamic character of implication, or, in general: $[\phi \rightarrow \psi] \wedge \chi \simeq \phi \rightarrow [\psi \wedge \chi]$
    - “Every player chooses a pawn, and (he) puts it on square one.”
      - $\forall x\phi \wedge \psi \simeq \forall x[\phi \wedge \psi]$
  - The purpose of this solution is to avoid giving dynamic interpretation to logical constants that are not consistently dynamic
  - However, it does seem in contrast with the goal of incorporating compositionality!

- **More on DPL and DRT**
  - Difference 1: How things are interpreted
    - DRT makes both a syntactic and a semantic distinction between conditions and DRSs
      - Conditions are interpreted like FOL sentences (i.e. in terms of their truth values)
      - DRSs are interpreted in terms of their verifying embeddings, which, I believe, is a fancy way of saying what other DRSs are accessible so that they are really interpreted in terms of how they bind anaphora
    - DPL doesn't make this kind of distinction; Everything is interpreted using the dynamic interpretation of the connectives
  - Difference 2: What connectives are used
    - DPL uses regular FOL with the exception that unbound variables are ok
    - DRT doesn't have quantifiers or conjunction
      - The discourse referents are how DRT does quantification and the list of conditions is like conjunction
  - What the differences mean in the end
    - There are other differences between these approaches, but, in the end, you can show that they're roughly the same
    - The <u>syntax for DRT</u> is somewhat better defined, but the <u>semantics for DPL</u> is better defined
    - The authors claim that DPL is more compositional, but even they can give examples where DPL has to fake the compositionality aspect

- DPL seems to rely on being able to give an (incorrect) FOL representation of the discourse before going through the DPL interpretation
  - *NOTE: DPL gives an interpretation of the discourse while DRT gives a representation of it!*
- DRT doesn't require this and claims to have an algorithmic way of determining what an anaphoric reference refers to
- In conclusion!
  - It seems like DPL is nice for giving an interpretation of a discourse, but it's hard to use.
  - DRT is relatively straightforward and pretty.
  - So, if we all we really care about is giving a representation of a discourse, DRT is the way to go.
  - And, luckily, DRT and DPL can roughly map to each other, so we can still use DPL to get an interpretation!