Lecture 27: Discourse Representation Theory

CS 181O
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Some slides based on those of Christina Unger

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.

Proper Names

- Ex: Alice admires Snow White

x, y

Alice(x)
SnowWhite(y)
admires(x,y)

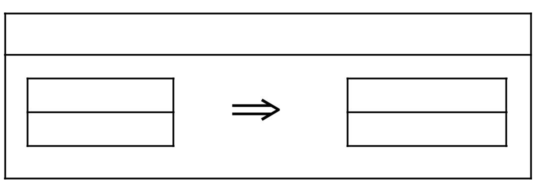
  - Where Alice(x) means ‘x is an individual named Alice’. **Rationale**: There can be many persons named Alice and it depends on the context which one is meant.
  - **Problem**: Alice admires Snow White does not mean someone called Alice admits someone called SnowWhite but expresses that a certain individual loves a certain other one. They are really constants!

Conditionals

- Conditional elements (and universal quantifiers) introduce subordinated DRSs.

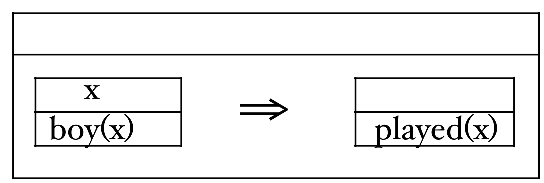
General Form

- Conditional structures are represented as duplex conditions of the following form:



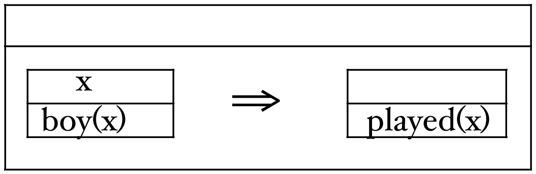
Example

- If a boy comes, he plays.



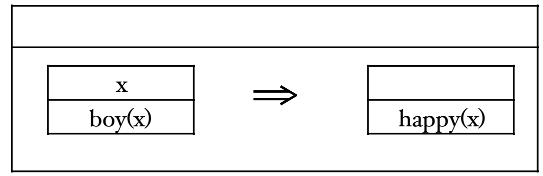
Example

- Universals are similar:
  - Every boy who came played.



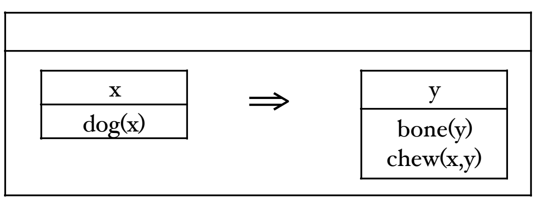
Example

Every boy is happy
Q restrictor scope



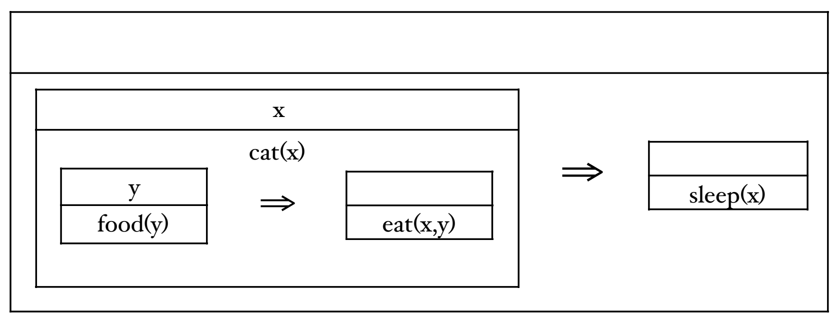
Another Example

Every dog chews a bone
Q restrictor scope



Example

Every cat, who eats all its food, sleeps
Q restrictor scope

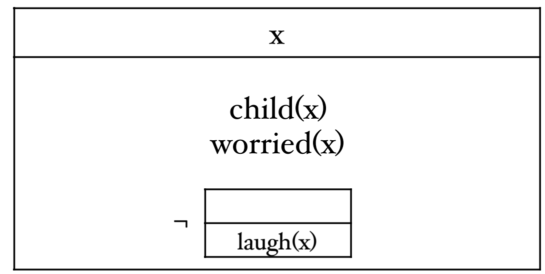


Referent markers

- The logical role played by a referent marker depends on the DRS-universe to which it belongs:
  - Referent markers belonging to the universe of the main DRS get an existential interpretation.
  - The role of referent markers in subordinate universes is determined by the principles governing the complex DRS conditions to which they belong.

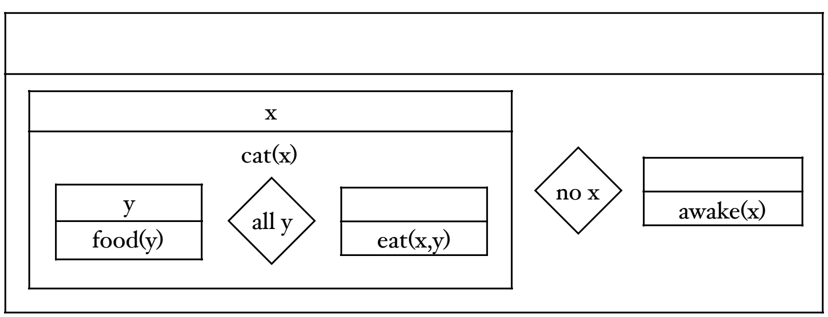
Negation

A worried child does not laugh



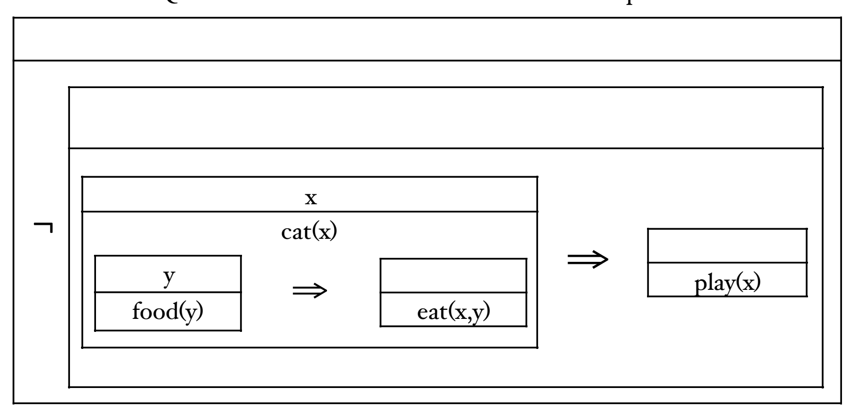
Example

No cat, who eats all its food, is awake
Q restrictor scope



Example

No cat, who eats all its food, plays
Q restrictor scope



DRS

- A discourse representation structure (DRS) consists of:
  - a finite set of referent markers (the discourse universe)
  - a finite set of conditions, which are one of the following:
    - atom (a predicate name applied to referent markers)
    - link (an expression $x = y$ or $x \neq y$, where x,y are referent markers)
    - complex condition (a negated DRS or implication of DRSs)

More Formally

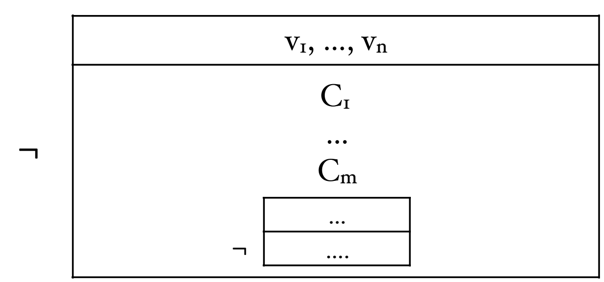
- Let Ref be a set of referent markers, Const a set of constants, and Reln sets of n-ary predicate constants. The set of DRSs and conditions is the smallest set that satisfies:
  - If $U \subseteq$ Ref and Con is a (possibly empty) set of conditions, then (U,Con) is a DRS.
  - If $t_1,\ldots,t_n \in \text{Ref} \cup \text{Const}$ and $R \in \text{Rel}^n$,then$R(t_1,\ldots,t_n)$ and $t_i = t_j$ (for $1 \leq i, j \leq n$) are atomic conditions.
  - If D_1, D_2 are DRSs, $v \in$ Ref and Q is a quantifier, then $\neg D_1$ and $D_1 \langle Q\ v \rangle D_2$ are complex conditions.

Even More Formally

- Definition: Let *c* range over a set of constants, *P* over a set of predicates with given arity, and Q over quantifiers.
  - Markers $\mathbf{v} ::= v \mid \mathbf{v}'$
  - Terms $\mathbf{t} ::= c \mid \mathbf{v}$
  - Conditions $\mathbf{C} ::= P(\mathbf{t},\ldots,\mathbf{t}) \mid \mathbf{v} = \mathbf{t} \mid \mathbf{v} \neq \mathbf{t} \mid \neg\mathbf{D}$
  - DRSs $\mathbf{D} ::= (\{\mathbf{v},\ldots,\mathbf{v}\},\{\mathbf{C},\ldots,\mathbf{C}\})$
  - *Use convention,* $(\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m\}) \Rightarrow D$ *abbreviates* $\neg(\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m,\neg D\})$

Abbreviation

- *Use convention,* $(\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m\}) \Rightarrow D$ *abbreviates* $\neg(\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m,\neg D\})$



Observation

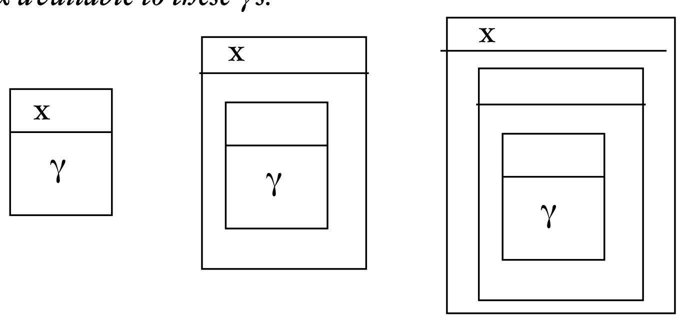
- Referents introduced in the context of scope-taking elements, such as negation and implications, are available as antecedent only inside this scope.
  - Each candidate thinks she is the best.
  - Each candidate speaks. #He is obnoxious.
  - John didn't eat anything. #It was delicious.

On the other hand ...

- Referents introduced by proper names are available as antecedents throughout the whole context.
  - John didn't convince Mary. She didn't like his views.
- Bottom line: Availability is captured by the structure of subordinated DRSs together with an accessibility relation among referent markers.

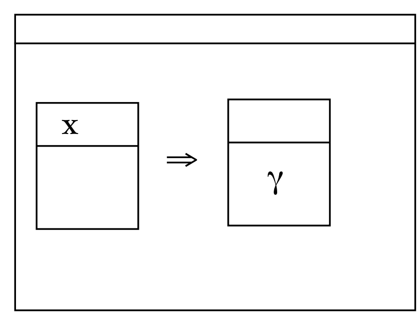
Accessibility

x available to these γs:



Accessibility

x available to these γs:



Accessibility

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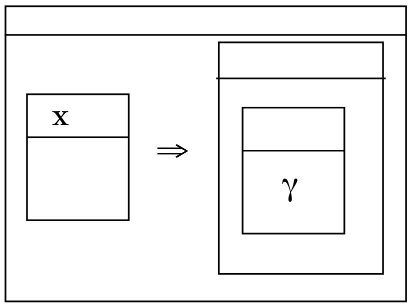


Models & Assignments

- Let M = ⟨U,I⟩ be a model, where
  - U is a non-empty domain
  - I is an interpretation function that maps
    - n-place predicate names to n-place relations on U
    - individual constants to members of U
- Let s and s be assignments that map reference markers to elements of U, then $s[x_1,\ldots,x_n]s'$ denotes that s is equal to s' except possibly on the values of $x_1,\ldots,x_n$

Embedding Semantics

- An assignment s verifies DRS D = ({v1,...,vn}, $\{C_1,\ldots,C_m\}$) in M if there is an assignment s' with $s[v_1,\ldots,v_n]s'$ which satisfies every member of $\{C_1,\ldots,C_m\}$ in M.
- *Remember, reference markers represent realizations of existential quantifiers.*

Embedding Semantics

- s satisfies $P(t_1,\ldots,t_n)$ in M iff $\langle V(t_1),\ldots,V(t_n)\rangle \in I(P)$, where $V(t_i)$ is $s(t_i)$ if t_i is a variable & $I(t_i)$ otherwise
- s satisfies v=t in M iff s(v) = V(t)
- s satisfies v≠t in M iff s(v) ≠ V(t)
- s satisfies ¬D in M iff s does not verify D in M
- *Can derive:*
  - s satisfies $D_1 \Rightarrow D_2$ iff all s with s[v]s' that satisfy all conditions in D_1 also satisfy D_2

Free Variables

- Structure D is true in M if there is an assignment which verifies D in M.
- From the definitions above, it follows that $(\emptyset,\{P(x,y)\})$ is true in M iff $(\{x,y\},\{P(x,y)\})$ is true in M, i.e. free variables are existentially quantified.

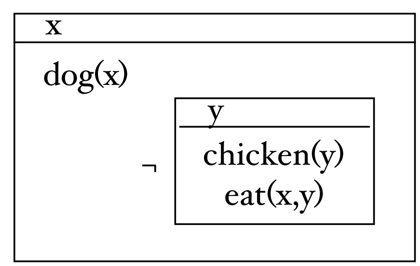
Expressive Power of DRT same as first-order logic

DRT to FOL

- °:DRS → FOL:
  - If $D = (\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m\})$ then
    $D^\circ = \exists v_1 \cdots \exists v_n.(C_1 \wedge \ldots \wedge C_m)$.
  - Atomic conditions: $C^\circ = C$
  - Negations: $(\neg D)^\circ = \neg D^\circ$
  - Can show:
    $(D_1 \Rightarrow D_2)^\circ = \forall v_1 \cdots v_n.((C_1 \wedge \ldots \wedge C_m) \rightarrow D^\circ_2)$ if
    $D_1 = (\{v_1,\ldots,v_n\},\{C_1,\ldots,C_m\})$

Example

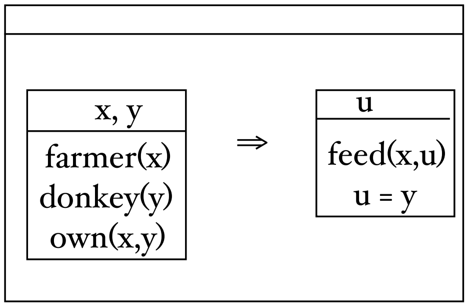
- A dog does not eat chicken



$\exists x.\ dog(x) \wedge \neg (\exists y.(chicken(y) \wedge eat(x,y))$

Donkey Sentences

- Every farmer who owns a donkey, feeds him



$\forall x\, \forall y\, .((\text{farmer}(x) \wedge \text{donkey}(y) \wedge \text{own}(x, y)) \rightarrow \exists u.(\text{feed}(x, u) \wedge u = y))$

FOL to DRT

- Atomic formulas: $C^* = (\varnothing, C)$
- Conjunctions: $(\phi \wedge \psi)^* = (\varnothing, \{\phi^*, \psi^*\})$
- Negations: $(\neg\phi)^* = (\varnothing, \neg\phi^*)$
- Existential quantification:
  $(\exists v.\phi)^* = (\textbf{first}\ \phi^* \cup \{v\}, \textbf{second}\ \phi^*)$
- Universal quantification: $(\forall v.\phi)^* = (\neg\exists v.\neg\phi)^*$

But want more …

- Provided static semantics,
  - but want dynamic semantics: context change!
- Contexts are often seen also as information states, i.e. as constituted by all the information collected by the discourse so far, together with a collection of salient individuals.
- Sentence interpreted as *context change potential*

Context Change Potential

Questions?