LING 364: Introduction to Formal Semantics

Lecture 22

April 6th

Administrivia

- **Homework 5**
  - on quantification
  - out today
  - due next Thursday

Exercise 1

- Truth Tables and Prolog

Exercise 1

- **Truth tables in Prolog**
- **Example**:
  - **% implies(P,Q,Result)**
  - implies(true,false,false).
  - implies(false,true,true).
  - implies(false,false,true).
  - implies(true,true,true).
  - **% or(P,Q,Result)**
  - or(true,true,true).
  - or(true,false,true).
  - or(false,true,true).
  - or(false,false,false).

P	⇒	Q
T	T	T
F	T	T
F	T	F
T	F	F

P	v	Q
T	T	T
F	T	T
F	F	F
T	T	F

remember: Prolog variables
are implicitly existentially quantified

Show using a Prolog query that implies/3 and or/3 are not equivalent

?- implies(P,Q,R1), or(P,Q,R2), \+ R1 = R2.

What should the outcome of this query be?

Exercise 1

- **Homework Question A (3pts)**
  - Using the Prolog query shown on the previous slide,
  - for what values of P and Q are implies/3 and or/3 incompatible?
  - Submit your run

Exercise 1

- Define truth table negation as follows:
  - **% neg(P,\+ P).**
  - neg(true,false).
  - neg(false,true).

P	¬P
T	F
F	T

- Show using a Prolog query that $P \Rightarrow Q$ is equivalent to $\neg P \vee Q$

?- implies(P,Q,R1), neg(P,**NotP**), or(**NotP**,Q,R2), \+ R1 = R2.

What should the outcome of this query be?

Exercise 1

- **Homework Question B (2pts)**
  - Define truth table and/3 in Prolog

P	∧	Q
T	T	T
F	F	T
F	F	F
T	F	F

- **Homework Question C (4pts)**
  - Using an appropriate Prolog query, and and/3,
  - Show that $\neg(P \vee Q) = \neg P \wedge \neg Q$ (*De Morgan's Rule*)
  - Submit your run

Exercise 1

- **Homework Question D (4pts)**
  - Using an appropriate Prolog query,
  - Show that $\neg(P \land Q) = \neg P \lor \neg Q$
  - (another side of *De Morgan's Rule*)
  - Submit your run

Exercise 1

- Summary
  - Submit answers to questions A through D
  - Points:
  - A: 3pts
  - B: 2pts
  - C: 4pts
  - D: 4pts
  - Total: 13 pts

Exercise 2

- Universal Quantification and Sets

Exercise 2

- **Assume meaning grammar:**

```
s(M) --> qnp(M), vp(P), {predicate2(M,P)}.
qnp(M) --> q(M), n(P), {predicate1(M,P)}.
q((findall(_X,_P1,L1),findall(_Y,_P2,L2),subset(L1,L2))) --> [every].
n(woman(_)) --> [woman].
vp(M) --> v(M), np(X), {saturate2(M,X)}.
v(likes(_X,_Y)) --> [likes].
np(ice_cream) --> [ice,cream].
```

```
saturate1(P,X) :- arg(1,P,X).
saturate2(P,X) :- arg(2,P,X).

subset([],_).
subset([X|L1],L2) :- member(X,L2),
    subset(L1,L2).
member(X,[X|_]).
member(X,[_|L]) :- member(X,L).

predicate1((findall(X,P,_),_),P) :-
    saturate1(P,X).
predicate2((_,(findall(X,P,_),_)),P) :-
    saturate1(P,X).
```

every has semantics:
$\{X: P_1(X)\} \subseteq \{Y: P_2(Y)\}$
e.g.
every woman likes ice cream
$\{X: woman(X)\} \subseteq \{Y: likes(Y, ice\_cream)\}$

Exercise 2

- Using the meaning grammar, we can compute a meaning expression for:
  - every woman likes ice cream

  using the Prolog query:
  - ?- s(M,[every,woman,likes,ice,cream],[]).
  - M = findall(A,woman(A),B),findall(C,likes(C,ice_cream),D),subset(B,D)

Exercise 2

- We can evaluate this meaning expression for various possible worlds using call/1
- For example, given the database:
  - woman(mary). woman(jill).
  - likes(john,ice_cream). likes(mary,ice_cream).
  - likes(jill,ice_cream).
- we can evaluate:
  - ?- s(M,[every,woman,likes,ice,cream],[]), call(M).
- the call is:
  - findall(A,woman(A),B),findall(C,likes(C,ice_cream),D),subset(B,D).
- with
  - B and D being [mary,jill] and [john,mary,jill] respectively

Exercise 2

- **Homework Question A (4pts)**
  - Modify the meaning grammar to handle the sentence
    - John likes ice cream
- **Homework Question B (2pts)**
  - Evaluate *John likes ice cream* against the database from the previous slide
  - Submit your run

Exercise 2

- **Homework Question C (10pts)**
  - Treating names as Generalized Quantifiers (*see below*),
  - Further modify the meaning grammar to handle the sentences
    - Every woman and John likes ice cream
    - John and every woman likes ice cream
  - Evaluate the sentences and submit your runs

Define set union as follows:
% L1 ∪ L2 = L3 *"L3 is the union of L1 and L2"*
union(L1,L2,L3) :- append(L1,L2,L3).

Recall Lecture 21

Example

every baby and John likes ice cream

$[_{NP}[_{NP}$ every baby] and $[_{NP}$ John]] likes ice cream

$(\{X: baby(X)\} \cup \{X: john(X)\}) \subseteq \{Y: likes(Y,ice\_cream)\}$

note: set union (∪) is the translation of "*and*"

Exercise 2

- Summary
  - Answer questions A, B and C
  - A: 4pts
  - B: 2pts
  - C: 10pts
  - Total: 16pts

Exercise 3

- Other quantifiers as generalized quantifiers

Exercise 3

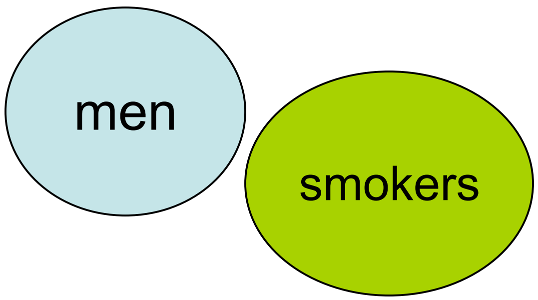
- Other quantifiers can also be expressed using set relations between two predicates:

  Example:

  no: $\{X: P_1(X)\} \cap \{Y: P_2(Y)\} = \emptyset$

  $\cap$ = set intersection

  $\emptyset$ = empty set



  no man smokes

  $\{X: man(X)\} \cap \{Y: smokes(Y)\} = \emptyset$

  should evaluate to true for all possible worlds where there is no overlap between men and smokers

Exercise 3

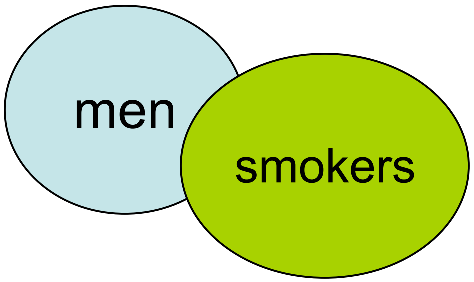
- Other quantifiers can also be expressed using set relations between two predicates:

  Example:

  some: $\{X: P_1(X)\} \cap \{Y: P_2(Y)\} \neq \varnothing$

  $\cap$ = set intersection

  $\varnothing$ = empty set



  some men smoke

  $\{X: man(X)\} \cap \{Y: smokes(Y)\} \neq \varnothing$

Exercise 3

- **Homework Question A (8pts)**
  - Modify the meaning grammar given in exercise 2 to handle the sentence:
  - *No woman likes ice cream*
  - Evaluate it against the database
- **Homework Question B (8pts)**
  - Modify the meaning grammar given in exercise 2 to handle the sentence:
  - *Some women like ice cream*
  - Evaluate it against the database

Exercise 3

- **Summary**
  - Submit parts A and B
  - and the runs
  - A: 8pts
  - B: 8pts
  - Total: 16pts

Summary

- **PLEASE SUBMIT EVERYTHING IN ONE FILE!**
- Exercises
- 1: 13pts
- 2: 16pts
- 3: 16pts
- Grand total: 35pts