LING 364: Introduction to Formal Semantics

Lecture 23

April 11th

Administrivia

- **Homework 4**
  - graded
  - you should get it back today

Administrivia

- **this Thursday**
  - computer lab class
  - help with homework 5
  - meet in SS 224

Today’s Topics

- **Homework 4 Review**

- **Finish with**
  - Chapter 6: Quantifiers
  - Quiz 5 (end of class)

Homework 4 Review

- **Questions 1 and 2**
- **Worlds**
  - w1 → {A,B} horse(a). horse(b).
  - w2 → {B,C} horse(b). horse(c).
  - w3 → {A,B,C} horse(a). horse(b). horse(c).
  - w4 → ∅ :- dynamic horse/1.
  - *or* ?- assert(horse(a)), retract(horse(a)).
  - *or* ?- set_prolog_flag(unknown,fail).
  - w5 → {A,B,C,D,E} horse(a). horse(b). horse(c). horse(d).
  - horse(e).
  - w6 → {A,B,C,D,E,F} horse(a). horse(b). horse(c). horse(d).
  - horse(e). horse(f).

Homework 4 Review

- Prolog definitions common to worlds $W_1,..,W_6$:
  - horses(Sum) :-
  - findall(X,horse(X),L),
  - sum(L,Sum).
  - sum(L,X+Y) :- pick(X,L,Lp), pick(Y,Lp,_).
  - sum(L,X+Sum) :- pick(X,L,Lp), **sum**(Lp,Sum).
  - pick(X,[X|L],L).
  - pick(X,[_|L],Lp) :- pick(X,L,Lp).

Homework 4 Review

- **Questions 1 and 2**
- **Answers to the query**
  - ?- findall(PL,horses(PL),L), length(L,N).
  - w1 → {A,B} L = [a+b] N=1
  - w2 → {B,C} L = [b+c] N=1
  - w3 → {A,B,C} L = [a+b,a+c,b+c,a+(b+c) N=4
  - w4 → ∅ L = [] N=0
  - w5 → {A,B,C,D,E} L = [a+b,a+c,a+d,a+e,b+c,b+d,b+e,c+d,c+e,d+e, a+(b+c),a+(b+d),a+(b+e),a+(c+d),a+(c+e),a+(d+e), a+(b+(c+d)),a+(b+(c+e)),a+(b+(d+e)), a+(b+(c+(d+e))),a+(c+(d+e)),b+(c+d), b+(c+e),b+(d+e),b+(c+(d+e)),c+(d+e)]
  - **total**: **26**

The number of combinations is as follows, where number = n and number_chosen = k:

$$\binom{n}{k} = \frac{P_{k,n}}{k!} = \frac{n!}{k!(n-k)!}$$

where:

$$P_{k,n} = \frac{n!}{(n-k)!}$$

  - 2 horses = ${}_5C_2$ = 5!/(2!3!) =10
  - 3 horses = ${}_5C_3$ = 5!/(3!2!) =10

4 horses = ${}_5C_4$ = 5!/(4!1!) =5

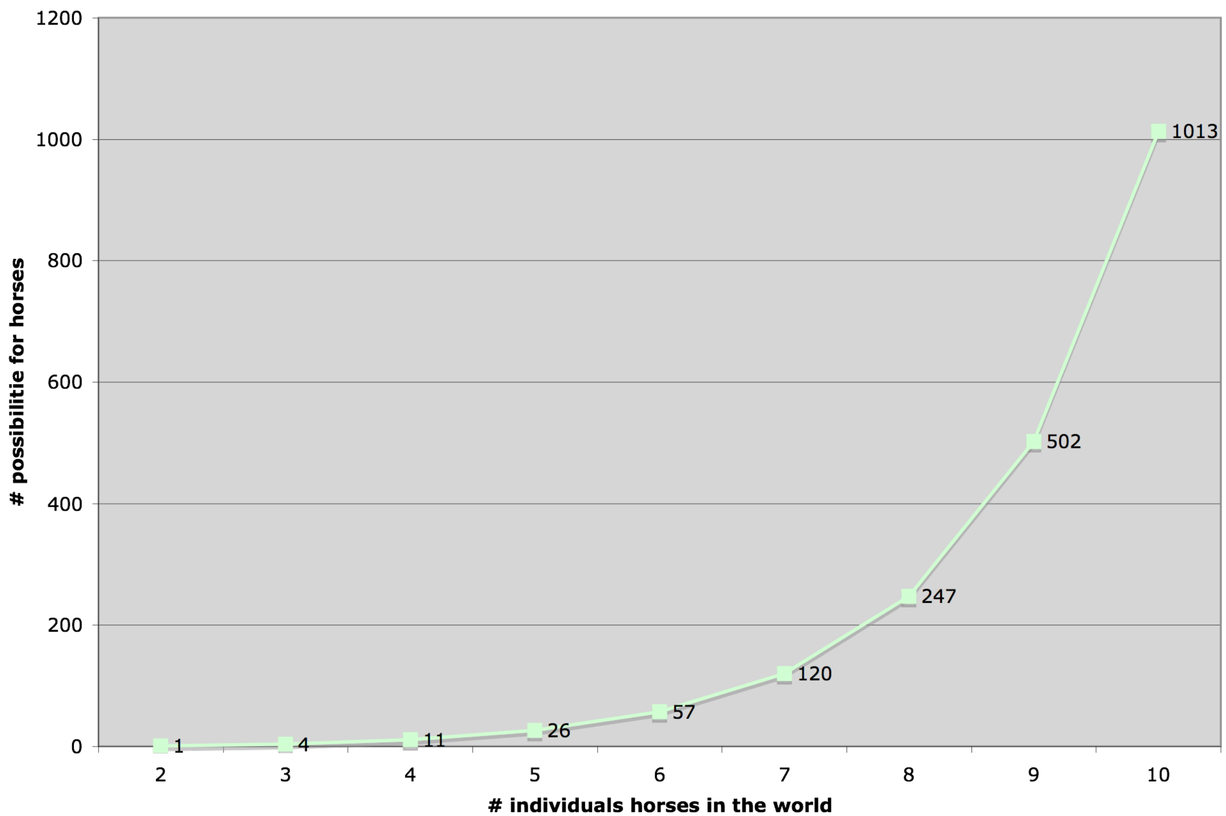
5 horses = 1

Homework 4 Review

- **Questions 1 and 2**
- **Answers to the query**
  - ?- findall(PL,horses(PL),L), length(L,N).
  - w6 → {A,B,C,D,E,F}
  - L=[a+b,a+c,a+d,a+e,a+f,b+c,b+d,b+e,b+f,c+d,c+e,c+f,d+e,d+f,e+f,
  - a+(b+c),a+(b+d),a+(b+e),a+(b+f),a+(c+d),a+(c+e),a+(c+f),a+(d+e),a+(d+f),a+(e+f),
  - a+(b+(c+d)),a+(b+(c+e)),a+(b+(c+f)),a+(b+(d+e)),a+(b+(d+f)),a+(b+(e+f)),
  - a+(b+(c+(d+e))),a+(b+(c+(d+f))),a+(b+(c+(e+f))),
  - a+(b+(c+(d+(e+f)))),
  - a+(b+(d+(e+f))),
  - a+(c+(d+e)),a+(c+(d+f)),a+(c+(e+f)),
  - a+(c+(d+(e+f))),
  - a+(d+(e+f)),
  - b+(c+d),b+(c+e),b+(c+f),b+(d+e),b+(d+f),b+(e+f),
  - b+(c+(d+e)),b+(c+(d+f)),b+(c+(e+f)),
  - b+(c+(d+(e+f))),
  - b+(d+(e+f)),
  - c+(d+e),c+(d+f),c+(e+f),c+(d+(e+f)),d+(e+f)]

2 horses = ${}_6C_2$ = 6!/(2!4!) =15
3 horses = ${}_6C_3$ = 6!/(3!3!) =20
4 horses = ${}_6C_4$ = 6!/(4!2!) =15
5 horses = ${}_6C_5$ = 6!/(5!1!) =6
6 horses = ${}_6C_1$ = 1
Total: **57**

Homework 4 Review



Homework 4 Review

- **Question 3:**
  - What is the Prolog query for “three horses”?
- **Answer**
  - Notice all cases of threes are of pattern/form _+(_+_) where ***each*** _ represents ***an individual horse***
    - e.g. a+(b+c),a+(b+d),a+(b+e),a+(c+d),a+(c+e),a+(d+e)
  - **Query (1st attempt)**
    - ?- findall(PL,(horses(PL),PL=_+(_+_)),L).
  - Example (W_5)
    - L=[a+(b+c),a+(b+d),a+(b+e),a+(c+d),a+(c+e),a+(d+e),a+(b+(c+d)),a+(b+(c+e)),a+(b+(d+e)),a+(b+(c+(d+e))),a+(c+(d+e)),b+(c+d),b+(c+e),b+(d+e),b+(c+(d+e)),c+(d+e)]
    - Total: 16 ***(but answer should be 10!)***

Homework 4 Review

- **Question 3:**
  - What is the Prolog query for “three horses”?
- **Answer**
  - **Query (2nd attempt)**
    - ?- findall(PL,(horses(PL),PL=_+(_+H),\+H=_+_),L), length(L,N).
  - Example (W_5)
    - L=[a+(b+c),a+(b+d),a+(b+e),a+(c+d),a+(c+e),a+(d+e),b+(c+d), b+(c+e),b+(d+e),c+(d+e)]
    - N=10 (correct)

Homework 4 Review

- **Question 3:**
  - What is the Prolog query for “three horses”?
- **Another way to deal with the question:**
  - recognize that notation Horse+Sum from the given definition:
  - sum(L,X+Y) :- pick(X,L,Lp), pick(Y,Lp,_).
  - sum(L,X+Sum) :- pick(X,L,Lp), **sum**(Lp,Sum).
  - is isomorphic to [Head|Tail] list notation (here: + is equivalent to |)
- Write a recursive length predicate, call it len/2, for Horse+Sum
  - len(_+Sum,N) :- !, len(Sum,M), N is M+1.
  - len(_,1).
- **Query becomes:**
  - ?- findall(PL,(horses(PL),**len(PL,3)**),L).

Homework 4 Review

- **Question 4:**
  - How would you write the query for “the three horses”?
- **Clue** (*given in lecture slides*)
  - ?- findall(X,dog(X),List), length(List,1).
  - encodes the definite description “the dog”
    - i.e. *query holds (i.e. is true) when dog(X) is true and there is a unique X in a given world*
- *Combine this clue with the answer to Question 3*
- **Resulting Query**
  - ?- findall(PL,(horses(PL),PL=_+(_+H),\+H=_+_),L), length(L,1).
  - Under the assumption that everything is equally salient, query is true for world W_3 only!
  - L = [a+(b+c)]
  - Worlds W_1,W_2 and W_4 have too few horses, and worlds W_5 and W_6 have too many.

Back to Chapter 6

Negative Polarity Items

- **Negative Polarity Items (NPIs)**
- **Examples**:
  - ever, any
- **Constrained distribution**:
  - have to be *licensed* in some way
  - grammatical in a “negated environment” or “question”

- **Examples**:
  - (13a) Shelby won’t ever bite you
  - (13b) Nobody has any money
  - (14a) *Shelby will ever bite you
  - (14b) *Noah has any money
  - *= ungrammatical
  - (15a) Does Shelby ever bite?
  - (15b) Does Noah have any money?

Negative Polarity Items

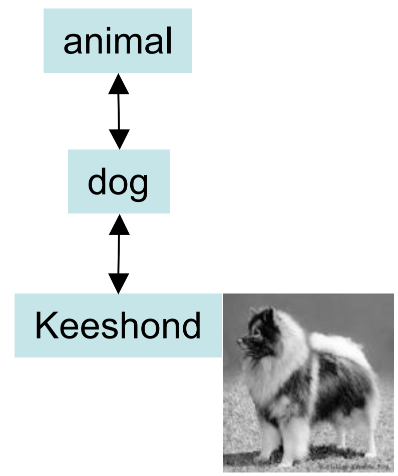
- Inside an *if-clause*:
  - (16a) If Shelby ever bites you, I'll put him up for adoption
  - (16b) If Noah has any money, he can buy some candy
- Inside an *every-NP*:
  - (17a) Every dog which has ever bitten a cat feels the admiration of other dogs
  - (17b) Every child who has any money is likely to waste it on candy
- Not inside a *some-NP*:
  - (17a) Some dog which has ever bitten a cat feels the admiration of other dogs
  - (17b) Some child who has any money is likely to waste it on candy

Not to be confused with free choice (FC) *any* (meaning: ∀): *any man can do that*

Downwards and Upwards Entailment (DE & UE)

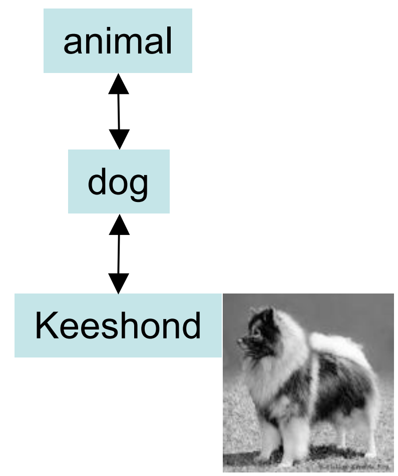
- class ⇄ super-class

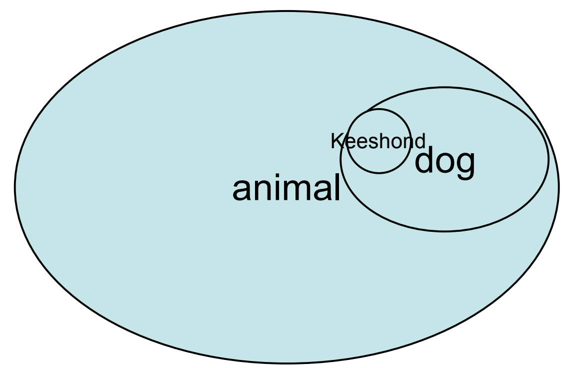
- **Example**:
  - **hyponym** ⇄ **hypernym**
  - dog ⇄ animal
  - Keeshond ⇄ dog
- **Inferencing**:
  - non-negative sentence: **upwards**
  - (23) I have a dog (*entails*)
  - (23b) I have an animal
  - I have a Keeshond (invalid inference)
  - negative sentence: **downwards**
  - (24a) I don't have a dog (*entails*)
  - (24b) I don't have a Keeshond
  - I don't have an animal (invalid inference)



Downwards and Upwards Entailment (DE & UE)

- Quantifier **every** has semantics
  - $\{X: P_1(X)\} \subseteq \{Y: P_2(Y)\}$
  - e.g. every woman likes ice cream
  - {X: woman(X)} ⊆ {Y:likes(Y,ice_cream)}
- **Every** is **DE for P_1** and UE for P_2
- Examples:
- (25) a. Every dog barks
- b. Every Keeshond barks (valid)
- c. Every animal barks (invalid)
  - semantically, “Keeshond” is a sub-property or subset with respect to the set “dog”





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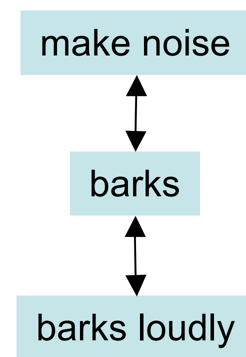
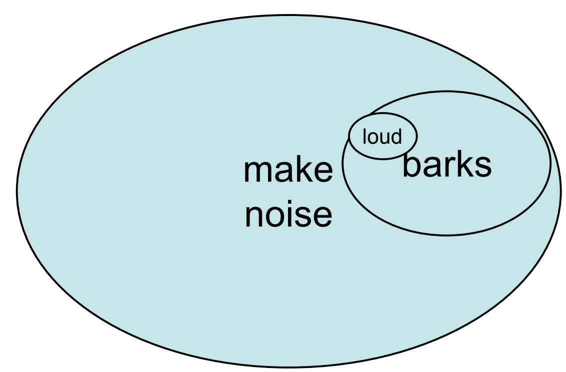
  - $\{X: P_1(X)\} \subseteq \{Y: P_2(Y)\}$
  - e.g. every woman likes ice cream
  - $\{X: woman(X)\} \subseteq \{Y: likes(Y, ice\_cream)\}$
- **Every** is DE for P_1 and **UE for $\mathbf{P_2}$**
- Examples:
- (25) a. Every dog barks
-         d. Every dog barks loudly   (invalid)
-         c. Every dog makes noise   (valid)
  - semantically, “barks loudly” is a subset with respect to the set “barks”, which (in turn) is a subset of the set “makes noise”





Downwards and Upwards Entailment (DE & UE)

- **Inferencing**:
  - **non-negative sentence**: **UE**
  - (23) I have a dog (*entails*)
  - (23b) I have an animal
  - I have a Keeshond (invalid)
  - **negative sentence**: **DE**
  - (24a) I don't have a dog (*entails*)
  - (24b) I don't have a Keeshond
  - I don't have an animal (invalid)
- **NPI-Licensing**:
  - **non-negative sentence: UE**
  - (14a) *Shelby will ever bite you
  - (14b) *Noah has any money
  - **negative sentence: DE**
  - (13a) Shelby won't ever bite you
  - (13b) Nobody has any money

Generalization:
NPIs like *ever* and *any* are licensed by DE

Downwards and Upwards Entailment (DE & UE)

- Inside an *every-NP*:
  - (17a) [Every [dog][which has ever bitten a cat]] feels the admiration of other dogs
  - (17b) [Every [child][who has any money]] is likely to waste it on candy
- Explanation:
  - **every** is **DE for P_1** and UE for P_2
  - $\{X: P_1(X)\} \subseteq \{Y: P_2(Y)\}$
- Inside an *every-NP*:
  - (17a) P_1 = [dog][which has ever bitten a cat]
  - (17b) P_1 = [child][who has any money

Generalization:
NPIs like *ever* and *any* are licensed by DE

Quiz 5

- Question 1: Is **Some** UE or DE for P_1 and P_2?
  - Lecture 22 (Homework 5 Question 3)
    - *some*: $\{X: P_1(X)\} \cap \{Y: P_2(Y)\} \neq \varnothing$
  - Justify your answer using examples of valid/invalid inferences starting from
    - Some dog barks
- Question 2: Is **No** UE or DE for P_1 and P_2?
  - Lecture 22 (Homework 5 Question 3)
    - *no*: $\{X: P_1(X)\} \cap \{Y: P_2(Y)\} = \varnothing$
  - Use
    - No dog barks