Lecture 11: Database Manipulation and Collecting Solutions

- Exercises
  – Solutions to exercises LPN chapter 10
- Theory
  – Discuss database manipulation in Prolog
  – Discuss built-in predicates that collect all solutions to a problem into a single list

Solution to Exercise 10.1

```
p(1).
p(2) :- !.
p(3).
```

Suppose we have the given database. Write all of Prolog's answers to the following queries.

```
?- p(X).
X = 1 ;
X = 2.

?- p(X),p(Y).
X = Y, Y = 1 ;
X = 1,
Y = 2 ;
X = 2,
Y = 1 ;
X = Y, Y = 2.

?- p(X),!,p(Y).
X = Y, Y = 1 ;
X = 1,
Y = 2.
```

Solution to Exercise 10.2

```
class(Number,positive) :- Number > 0.
class(0,zero).
class(Number, negative) :- Number < 0.
```

First, explain what the program above does.

The predicate class is true if the second argument is `positive` *if the first is a positive number,* `negative` *if the first is negative and* zero *if the first is 0.*

Second, improve it by adding green cuts.

```
class(Number,positive) :- Number > 0, !.
class(0,zero) :- !.
class(Number, negative) :- Number < 0.
```

Lecture 11: Database Manipulation and Collecting Solutions

- Theory
  - Discuss database manipulation in Prolog
  - Discuss built-in predicates that collect all solutions to a problem into a single list

Database Manipulation

- Prolog has five basic database manipulation commands:
  - assert/1
  - asserta/1
  - assertz/1
  - retract/1
  - retractall/1

Database Manipulation

- Prolog has five basic database manipulation commands:

  - assert/1
  - asserta/1
  - assertz/1

  Adding information

  - retract/1
  - retractall/1

  Removing information

Start with an empty database

Start with an empty database

```
?- listing.
yes
```

Using assert/1

```
?- assert(happy(mia)).
yes
```

Using assert/1

```
happy(mia).
```

```
?- assert(happy(mia)).
yes
?-
```

Using assert/1

```
happy(mia).
```

```
?- assert(happy(mia)).
yes
?- listing.
happy(mia).
?-
```

Using assert/1

```
happy(mia).
```

```
?- assert(happy(mia)).
yes
?- listing.
happy(mia).
?- assert(happy(vincent)),
     assert(happy(marsellus)),
     assert(happy(butch)), assert
     (happy(vincent)).
```

Using assert/1

```
happy(mia).
happy(vincent).
happy(marsellus).
happy(butch).
happy(vincent).
```

```
?- assert(happy(mia)).
yes
?- listing.
happy(mia).
?- assert(happy(vincent)),
     assert(happy(marsellus)),
     assert(happy(butch)), assert
     (happy(vincent)).
yes
?-
```

Changing meaning of predicates

- The database manipulations have changed the meaning of the predicate **happy/1**
- More generally:
  - database manipulation commands give us the ability to change the meaning of predicates during runtime

Dynamic and Static Predicates

- Predicates whose meaning changing during runtime are called **dynamic** predicates
  - happy/1 is a dynamic predicate
  - Some Prolog interpreters require a declaration of dynamic predicates
- Ordinary predicates are sometimes referred to as **static** predicates

Asserting rules

```
happy(mia).
happy(vincent).
happy(marsellus).
happy(butch).
happy(vincent).
```

```
?- assert( (naive(X):- happy(X)).
```

Asserting rules

```
happy(mia).
happy(vincent).
happy(marsellus).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- assert( (naive(X):- happy(X)).
yes
?-
```

Removing information

- Now we know how to add information to the Prolog database
  - We do this with the **assert**/1 predicate
- How do we remove information?
  - We do this with the **retract**/1 predicate, this will remove one clause
  - We can remove several clauses simultaneously with the **retractall**/1 predicate

Using retract/1

```
happy(mia).
happy(vincent).
happy(marsellus).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- retract(happy(marsellus)).
```

Using retract/1

```
happy(mia).
happy(vincent).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- retract(happy(marsellus)).
yes
?-
```

Using retract/1

```
happy(mia).
happy(vincent).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- retract(happy(marsellus)).
yes
?- retract(happy(vincent)).
```

Using retract/1

```
happy(mia).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- retract(happy(marsellus)).
yes
?- retract(happy(vincent)).
yes
```

Using retract/1

```
happy(mia).
happy(butch).
happy(vincent).

naive(A):- happy(A).
```

```
?- retract(happy(X)).
```

Using retract/1

```
naive(A):- happy(A).
```

```
?- retract(happy(X)).
X=mia;
X=butch;
X=vincent;
no
?-
```

Using asserta/1 and assertz/1

- If we want more control over where the asserted material is placed we can use the variants of assert/1:
  - **asserta**/1
    places asserted matieral at the **beginning** of the database
  - **assertz**/1
    places asserted material at the **end** of the database

Memoisation

- Database manipulation is a useful technique
- It is especially useful for storing the results to computations, in case we need to recalculate the same query
- This is often called **memoisation** or **caching**

Example of memoisation

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
     lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
     Res is (X+Y) * (X+Y),
     assert(lookup(X,Y,Res)).
```

Example of memoisation

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).
```

```
?- addAndSquare(3,7,X).
```

Example of memoisation

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).

lookup(3,7,100).
```

```
?- addAndSquare(3,7,X).
X=100
yes
?-
```

Example of memoisation

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).

lookup(3,7,100).
```

```
?- addAndSquare(3,7,X).
X=100
yes
?- addAndSquare(3,4,X).
```

Example of memoisation

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).

lookup(3,7,100).
lookup(3,4,49).
```

```
?- addAndSquare(3,7,X).
X=100
yes
?- addAndSquare(3,4,X).
X=49
yes
```

Using retractall/1

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
     lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
     Res is (X+Y) * (X+Y),
     assert(lookup(X,Y,Res)).

lookup(3,7,100).
lookup(3,4,49).
```

```
?- retractall(lookup(_, _, _)).
```

Using retractall/1

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
     lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
     Res is (X+Y) * (X+Y),
     assert(lookup(X,Y,Res)).
```

```
?- retractall(lookup(_, _, _)).
yes
?-
```

Red and Green Cuts

Red cut

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).
```

Red and Green Cuts

Red cut

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).
```

Green cuts

```
:- dynamic lookup/3.

addAndSquare(X,Y,Res):-
    lookup(X,Y,Res), !.

addAndSquare(X,Y,Res):-
    \+ lookup(X,Y,Res), !,
    Res is (X+Y) * (X+Y),
    assert(lookup(X,Y,Res)).
```

A word of warning…

- A word of warning on database manipulation:
  - Often is a useful technique
  - But can lead to dirty, hard to understand code
  - It is non declarative, non logical
  - So should be used cautiously
- Prolog interpreters also differ in the way **assert/1** and **retract/1** are implemented with respect to backtracking
  - Either the assert or retract operation is cancelled over backtracking, or not

Consider this database

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- descend(martha,X).
X=charlotte;
X=caroline;
X=laura;
X=rose;
no
```

Collecting solutions

- There may be many solutions to a Prolog query
- However, Prolog generates solutions one by one
- Sometimes we would like to have *all* the solutions to a query in one go
- Needless to say, it would be handy to have them in a neat, usable format

Collecting solutions

- Prolog has three built-in predicates that do this: **findall**/3, **bagof**/3 and **setof**/3
- In essence, all these predicates collect all the solutions to a query and put them into a single list
- But there are important differences between them

findall/3

- The query

```
?- findall(O,G,L).
```

produces a list **L** of all the objects **O** that satisfy the goal **G**

  – Always succeeds

  – Unifies **L** with empty list if **G** cannot be satisfied

A findall/3 example

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- findall(X,descend(martha,X),L).
L=[charlotte,caroline,laura,rose]
yes
```

Other findall/3 examples

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- findall(f:X,descend(martha,X),L).
L=[f:charlotte,f:caroline,f:laura,f:rose]
yes
```

Other findall/3 examples

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- findall(X,descend(rose,X),L).
L=[ ]
yes
```

Other findall/3 examples

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- findall(d,descend(martha,X),L).
L=[d,d,d,d]
yes
```

findall/3 is sometimes rather crude

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):- child(X,Y).
descend(X,Y):- child(X,Z),
               descend(Z,Y).
```

```
?- findall(Chi,descend(Mot,Chi),L).
L=[charlotte,caroline,laura, rose,
   caroline,laura,rose,laura,rose,rose]
yes
```

bagof/3

- The query

```
?- bagof(O,G,L).
```

produces a list **L** of all the objects **O** that satisfy the goal **G**
  - Only succeeds if the goal **G** succeeds
  - Binds free variables in **G**

Using bagof/3

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):-
    child(X,Y).
descend(X,Y):-
    child(X,Z),
    descend(Z,Y).
```

```
?- bagof(Chi,descend(Mot,Chi),L).
Mot=caroline
L=[laura, rose];
Mot=charlotte
L=[caroline,laura,rose];
Mot=laura
L=[rose];
Mot=martha
L=[charlotte,caroline,laura,rose];
no
```

Using bagof/3 with ^

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):-
    child(X,Y).
descend(X,Y):-
    child(X,Z),
    descend(Z,Y).
```

```
?- bagof(Chi,Mot^descend(Mot,Chi),L).
L=[charlotte, caroline, laura, rose,
   caroline,laura,rose,laura, rose, rose]
```

setof/3

- The query

```
?- setof(O,G,L).
```

produces a sorted list **L** of all the objects **O** that satisfy the goal **G**
  - Only succeeds if the goal **G** succeeds
  - Binds free variables in **G**
  - Remove duplicates from **L**
  - Sorts the answers in **L**

Using setof/3

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):-
    child(X,Y).
descend(X,Y):-
    child(X,Z),
    descend(Z,Y).
```

```
?- bagof(Chi,Mot^descend(Mot,Chi),L).
L=[charlotte, caroline, laura, rose,
   caroline, laura, rose, laura, rose,
   rose]
yes

?-
```

Using setof/3

```
child(martha,charlotte).
child(charlotte,caroline).
child(caroline,laura).
child(laura,rose).

descend(X,Y):-
    child(X,Y).
descend(X,Y):-
    child(X,Z),
    descend(Z,Y).
```

```
?- bagof(Chi,Mot^descend(Mot,Chi),L).
L=[charlotte, caroline, laura, rose,
   caroline, laura, rose, laura, rose,
   rose]
yes

?- setof(Chi,Mot^descend(Mot,Chi),L).
L=[caroline, charlotte, laura, rose]
yes

?-
```

Solution to Exercise 11.1

```
q(foo,blug).
q(a,b).
q(1,2).
```

```
?- assert(q(a,b)), assertz(q(1,2)),
      asserta(q(foo,blug)).
```

Solution to Exercise 11.1

```
q(foo,blug).
q(a,b).
q(1,2).
```

```
?- assert(q(a,b)), assertz(q(1,2)),
         asserta(q(foo,blug)).
?- retract(q(1,2)), assertz( (p(X) :- h(X)) ).
```

Solution to Exercise 11.1

```
q(foo,blug).
q(a,b).
p(X) :- h(X)
```

```
?- assert(q(a,b)), assertz(q(1,2)),
       asserta(q(foo,blug)).
?- retract(q(1,2)), assertz( (p(X) :- h(X)) ).
```

Solution to Exercise 11.1

```
q(foo,blug).
q(a,b).
p(X) :- h(X)
```

```
?- assert(q(a,b)), assertz(q(1,2)),
      asserta(q(foo,blug)).
?- retract(q(1,2)), assertz( (p(X) :- h(X)) ).
?- retract(q(_,_)),fail.
```

Solution to Exercise 11.1

Possibility 1

```
q(foo,blug).
q(a,b).
p(X) :- h(X)
```

Possibility 2 (SWI Prolog)

```
p(X) :- h(X)
```

```
?- assert(q(a,b)), assertz(q(1,2)),
       asserta(q(foo,blug)).
?- retract(q(1,2)), assertz( (p(X) :- h(X)) ).
?- retract(q(_,_)),fail.
```

Solution to Exercise 11.2

```
q(blob,blug).      q(blaf,blag).      q(flab,blob).
q(blob,blag).      q(dang,dong).
q(blob,blig).      q(dang,blug).
```

```
?- findall(X,q(blob,X),List).
List = [blug, blag, blig].

?- findall(X,q(X,blug),List).
List = [blob, dang].

?- findall(X,q(X,Y),List).
List = [blob, blob, blob, blaf, dang, dang, flab].
```

Solution to Exercise 11.2

```
q(blob,blug).        q(blaf,blag).        q(flab,blob).
q(blob,blag).        q(dang,dong).
q(blob,blig).        q(dang,blug).
```

```
?- bagof(X,q(X,Y),List).
Y = blag,
List = [blob, blaf] ;
Y = blig,
List = [blob] ;
Y = blob,
List = [flab] ;
Y = blug,
List = [blob, dang] ;
Y = dong,
List = [dang].
```

Solution to Exercise 11.2

```
q(blob,blug).      q(blaf,blag).      q(flab,blob).
q(blob,blag).      q(dang,dong).
q(blob,blig).      q(dang,blug).
```

```
?- setof(X,Y ^ q(X,Y),List).
List = [blaf, blob, dang, flab].
```

Written Exam

Datum: Dienstag, den 6. September 2011

Zeit: 10.30-12.00

Ort: Appelstraße 4 (3703), Multimedia Hörsaal (Raum 023)

Art: Schriftlich

Hilfsmittel: Kein erlaubt

Stoff: Beide KI Vorlesung und Einfürung zu Prolog (50%-50%)

Sieh Beispiel Klausuren auf KI Webseite!

Viel Glück!