# 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 which meaning change 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 two 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

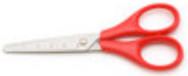
*Red cut*

```
:- 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

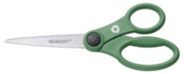


*Red cut*

```
:- 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*

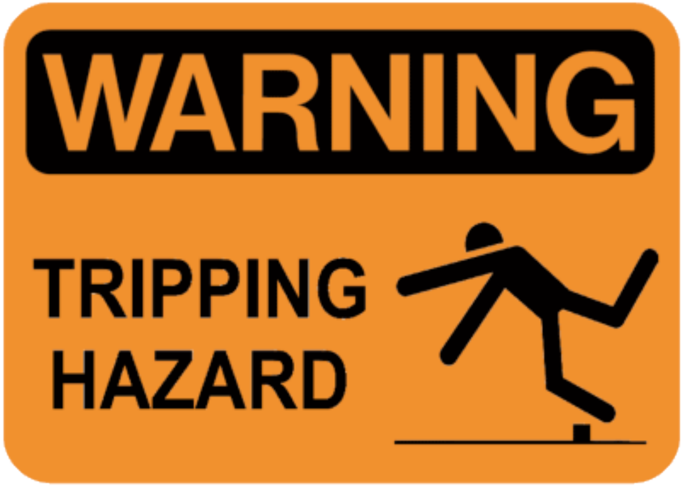
```
:- dynamic lookup/3.

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…

- Some thoughts on database manipulation:
  - Often a useful technique
  - But can lead to dirty, hard to understand code
  - It is non declarative, non logical
  - So should be used cautiously

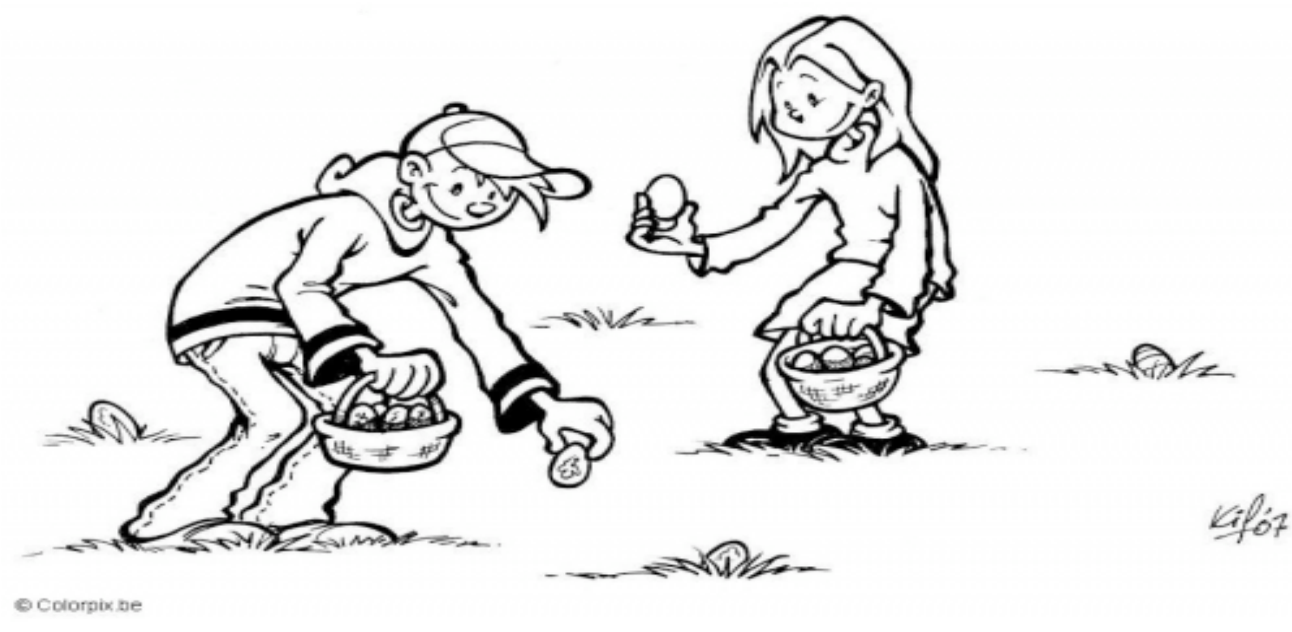


# Differences in implementation

- 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

# Collecting Solutions

- We now introduce some Prolog predicates useful for processing all solutions to a query in one go



# 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**

# Recall 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,Mot^descend(Mot,Chi),L).
L=[charlotte, caroline, laura, rose,
   caroline, laura, rose, laura, rose,
   rose]
yes

?-
```

# Compare this to 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

?-
```

# 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
- Exercises
  - Exercises of LPN: 11.1, 11.2, 11.3
  - Practical session