CSc 372

Comparative Programming Languages

23 : Prolog — The Database

Department of Computer Science
University of Arizona

collberg@gmail.com

Christian Collberg

Introduction

Manipulating the Database

- So far we have assumed that the Prolog database is static, i.e. that it is loaded once with the program and never changes thereafter.
- This is not necessarily true; we can add or remove facts and rules from the database at will.
- This is not necessarily good programming practice, but sometimes it is necessary and sometimes it makes for elegant programs.
- In a nutshell:
  1. Allows us to program with side effects.
  2. Justified under some circumstances.
  3. Often inefficient.

Operations on the Prolog Database

Assert

- `assert(X)` adds a clause to the database.
  Not defined in gprolog!
- `asserta(X)` adds a clause to the *beginning* of the database.
- `assertz(X)` adds a clause to the *end* of the database.
- `assert` always succeeds, and backtracking does not undo the assertion.

Assert. . .

- `assert` can be used in *machine learning* programs, program which learn new facts as they progress.
- In some Prolog implementations you have to specify whether a certain clause is dynamic (new clauses can be added to the database during execution) or static:

  ```
  :- dynamic(hanoi/5).
  ```

  This means that we can add and remove clauses with five arguments whose functor is `hanoi`.

Assert . . . – Example

- Write a program that learns the addresses of places in a city.
- This program assumes a Manhattan-style city layout: locations are given as the intersection of streets and avenues.

```
?- loc(whitehorse, Ave, St).
   Ave = 8, St = 11
?- loc(airport, Ave, St).
   -- this airport
   what avenue?  5.
   what street?  32.
   Ave = 5, St = 32
?- loc(airport, Ave, St).
   Ave = 5, St = 32
```

Assert . . . – Example

```
location(whitehorse, 8, 11).
location(microsoft, 8, 42).
location(condomeria, 8, 43).
location(plunket, 7, 32).

% Do we know the location of X?
loc(X, Ave, Str) :- location(X, Ave, Str), !.

% if not, learn it!
loc(X, Ave, Street) :-
   nonvar(X), var(Ave), var(Str),
   write('-- this '), write(X), nl,
   write('what avenue?  '), read(Ave),
   write('what street?  '), read(Street),
   assert(location(X, Ave, Str)).
```

Retract

- `retract(X)` removes the first clause that matches `X`.
- `assert` and `retract` behave differently on backtracking. When we backtrack through `assert` nothing happens. When we backtrack to `retract` Prolog continues searching the database trying to find another matching clause. If one is found it is removed.
- If the argument to `retract(clause(X))` contains some uninstantiated variables they will be instantiated.
- `retract(X)` fails when no matching clause can be found.

Retract. . .

- Backtracking does not undo the removal.

```
retractall(X) :-
   retract(X), fail.
retractall(X) :-
   retract((X :- Y)),
   fail.
retractall(_).
```

Clause

- `clause(X, Y)` finds all clauses in the database with head `X` and body `Y`.

```
append([], X, X).
append([A|B],C,[A|D]) :-
      append(B, C, D).

?- clause(append(X, Y, Z), T).
   X=[], Y=_3, Z=_3, Y=true ;
   X=[_4|_5], Y=_6, Z=[_4|_7],
      Y=append(_5, _6, _7) ;
   no
```

Clause...

- The goal `clause(X, Y)` instantiates `X` to the head of a goal (the left side of `:-`) and `Y` to the body.
- `X` can be just a variable (in which case it will match *all* the clauses in the database), a fully instantiated (*ground*) term, or a term which contains some uninstantiated variables.
- Note that a fact has a body `true`.

Clause...

List all the clauses whose head matches `X`.

```
list(X) :- clause(X, Y),
   print(X, Y),
   write('.'), nl, fail.
list(_).

print(X, true) :- !, write(X).
print(X, Y) :- write((X :- Y)).

?- list(append(X, Y, Z)).
   append([], _4, _4).
   append([_5|_6],_7,[_5|_8]) :-
         append(_6, _8, _8).
```

Clausal Representation of Data Structures

- Normally we represent a data structure using a combination of Prolog lists and structures.
- A graph can for example be represented as a list of edges, where each edge is represented by a binary structure:

  `[edge(a,b), edge(c,b), edge(a,d), edge(c,d)]`
- However, it is also possible to use *clauses* to represent data structures such as lists, trees, and graphs.
- It is usually not a good idea to do this, but sometimes it is useful, particularly when we are faced with a *static* data structure (one which does not change, or changes very little).

Clauses as Data Structures – Lists

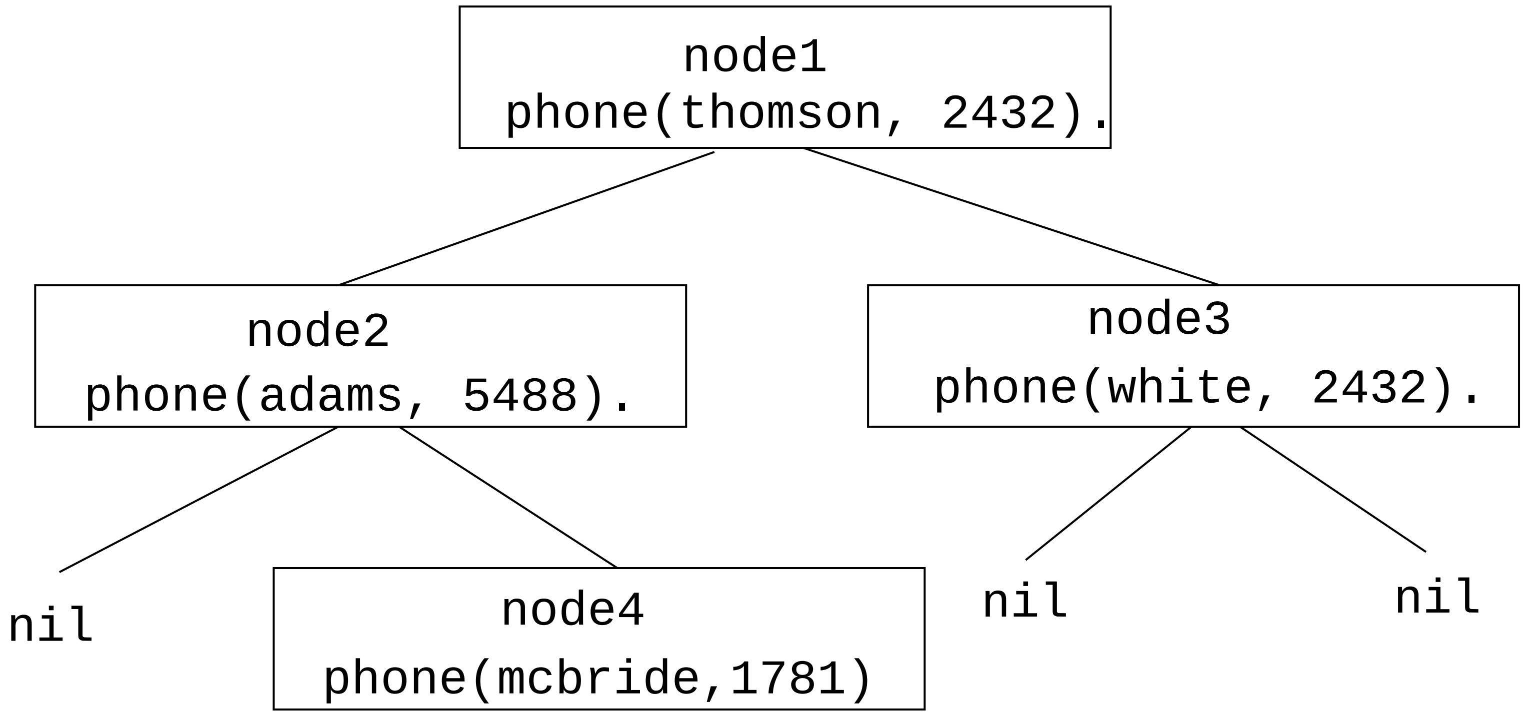
```
list(c).
list(h).
list(r).
list(i).
list(s).

process_list :- list(X), process_item(X), fail.
process_list.
```

Clauses as Data Structures – Trees

```
t(node1, node2, phone(thompson, 2432), node3).
t(node2, nil, phone(adams, 5488), node4).
t(node3, nil, phone(white, 2432), nil).
t(node4, nil, phone(mcbride, 1781), nil).
```

Clauses as Data Structures – Trees. . .



Clauses as Data Structures – Trees. . .

```
inorder(nil).
inorder(Node) :-
   t(Node, Left, P, Right),
   inorder(Left),
   write(P), nl,
   inorder(Right).

?- inorder(node1).
   phone(adams,5488)
   phone(mcbride,1781)
   phone(thompson,2432)
   phone(white,2432)
```

Clausal Representation...

- In general it is a bad idea to represent data in this way.
- Inserting and removing data has to be done using `assert` and `retract`, which are fairly expensive operations.
- However, in Prolog implementations which support *clause indexing*, storing data in clauses gives us a way to access information *directly*, rather than through sequential search.
- The reason for this is that *indexing* uses hash tables to access clauses.

Switches

Switches

- From *Prolog by Example*, Coelho & Cotta.
- In some cases it is a good idea to use global data rather than passing it around as a parameter.
- Assume we want to be able to switch between short and long error messages. Instead of extending every clause by an extra parameter (clumsy and inefficient) we use a global switch.
- The first clause in `turnon` will fire if the switch is already turned on.
- The first clause in `turnoff` fails if `Switch` was already off.
- The first clause in `flip` fails if `Switch` was turned off, in which case the second clause fires and the switch is turned on.

Switches. . .

```
turnon(Switch) :-
   call(Switch), !.
turnon(Switch) :-
   assert(Switch).

turnoff(Switch) :-
   retract(Switch).
turnoff(_).

flip(Switch) :-
   retract(Switch), !.
flip(Switch) :-
   assert(Switch).
```

Switches. . .

```
turnon(terse_mess).
      .....
flip(terse_mess).

message(C) :-
   terse_mes, write ('Error!'), nl, !.
message(C) :-
   write ('We are sorry to...'),
   write ('error has occurred near the symbol '),
   write(C), write('.  Please accept our...'),
   nl, !.
```

Memoization

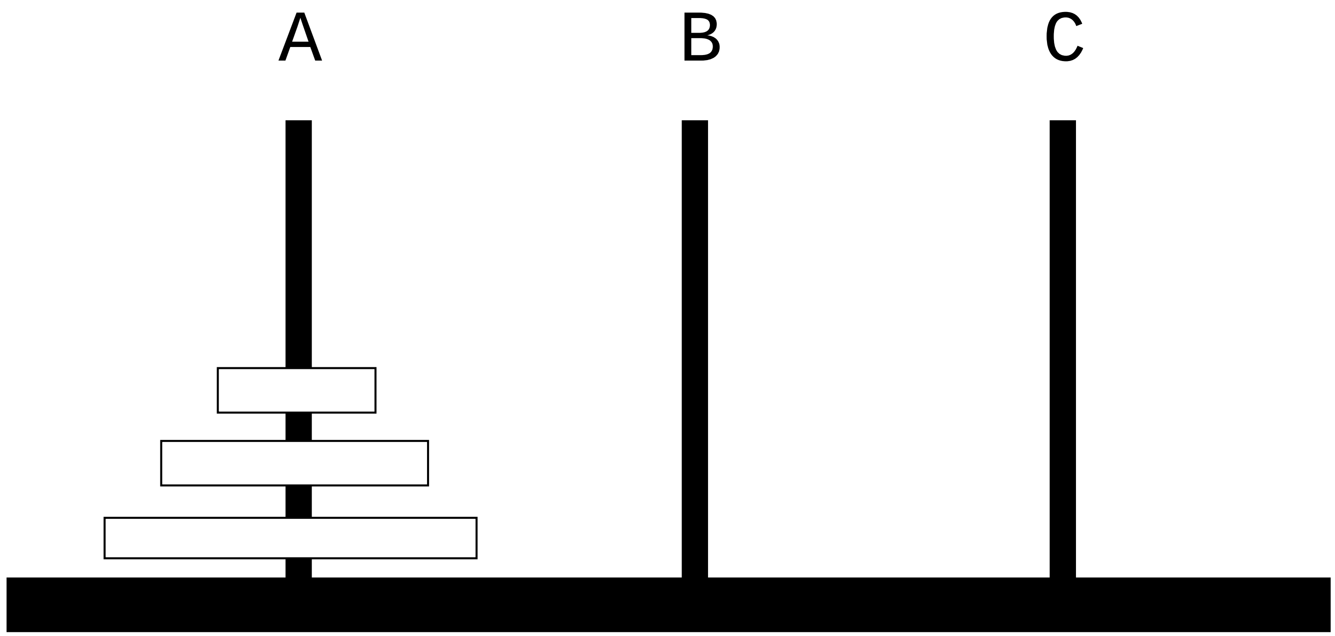
Memoization

- Many recursive program are extremely inefficient because they solve the same subproblem several times.
- In dynamic programming the idea is simply to store the results of a computation in a table, and when we try to solve the same problem again we retrieve the value from the table rather than computing the value once more.
- There is a variation of dynamic programming known as memoization.

Memoization – Towers of Hanoi

- I'm sure you've heard of the Towers of Hanoi problem. It is one first year computer science students are tortured with to no end.
- The problem is to move a number of disks from a peg A to a peg B, using a peg C as intermediate storage. Additionally, we are only allowed to put smaller disks onto larger disks.
- A recursive solution of the problem to move N disks from A to B is as follows:
  1. Move $N - 1$ disks from A to C.
  2. Move the remaining (largest) disk from A to B.
  3. Move the $N - 1$ disks from C to B.

Memoization – Towers of Hanoi. . .



Memoization – Towers of Hanoi. . .

```
:- op(100, xfx, to).

hanoi(1, A, B, C, [A to B]).
hanoi(N, A, B, C, Ms) :-
   N > 1,
   N1 is N-1,
   hanoi(N1, A, C, B, M1),
   hanoi(N1, C, B, A, M2),
   append(M1, [A to B|M2], Ms).

go(N, Moves) :-
   hanoi(N, a, b, c, Moves).
```

Memoization – Towers of Hanoi. . .

```
?- go(2,M).
   M = [a to c, a to b, c to b]

?- go(3,M).
   M = [a to b, a to c, b to c,
      a to b, c to a, c to b,
      a to b]

?- go(4,M).
   M = [a to c, a to b, c to b,
      a to c, b to a, b to c,
      a to c, a to b, c to b,
      c to a, b to a, c to b,
      a to c, a to b, c to b]
```

Memoization – Towers of Hanoi. . .

```
hanoi(1, A, B, C, [A to B]).
hanoi(N, A, B, C, Ms) :-
   N > 1, R is N-1,
   lemma(hanoi(R, A, C, B, M1)),
   hanoi(N1, C, B, A, M2),
   append(M1, [A to B|M2], Ms).

lemma(P) :- call(P),
         asserta((P :- !)).

go(N, Pegs, Moves) :-
   hanoi(N, A, B, C, Moves),
   Pegs=[A, B, C].
```

Memoization – Towers of Hanoi. . .

```
hanoi(1, _3, _5, _4, [_3 to _5]) :- !.
hanoi(2, _3, _4, _5,
      [_3 to _5, _3 to _4, _5 to _4]) :- !.
hanoi(3, _3, _5, _4,
      [_3 to _5, _3 to _4, _5 to _4,
      _3 to _5, _4 to _3, _4 to _5,
      _3 to _5]) :- !.
```

Example – Gensym

Example – Gensym

- From *Programming in Prolog*, Clocksin & Mellish.
- If we want to store data between different top-level queries, then using the database is our only option.
- In the following example we want to generate new atoms.
- In order to make this work, `gensym` has to store the number of atoms with a given prefix that it has generated so far. The clause `current_num(Root, Num)` is used for this purpose. There is one `current_num` clause for each kind of atom that we generate.

Example – Gensym. . .

```
gensym(Root, Atom) :-
    get_num(Root, Num),
    name(Root, Name1),
    int_name(Num, Name2),
    append(Name1, Name2, Name),
    name(Atom, Name).

get_num(Root, Num) :-
    retract(current_num(Root, Num1)),
    !, Num is Num1 + 1,
    asserta(current_num(Root, Num)).
get_num(Root, 1) :-
    asserta(current_num(Root, 1)).
```

Example – Gensym...

```
int_name(Int, List) :- int_name(Int, [], List).
int_name(I, Sofar, [C|Sofar]) :-
   I<10, !, C is I+48.
int_name(I, Sofar, List) :-
   Tophalf is I/10, Bothalf is I mod 10,
   C is Bothalf + 48,
   int_name(Tophalf, [C|Sofar], List).

?- gensym(chris, A).
   A = chris1
?- gensym(chris, A).
   A = chris2
?- gensym(chris, A).
   A = chris3
```

Readings and References

- Read Clocksin-Mellish, Chapter 6.