

Logic Programming

Efficiency Issues

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Efficiency Issues in Prolog

- ▶ Narrow the Search
- ▶ Let Unification do the Work
- ▶ Avoid `assert` and `retract`
- ▶ Understand Tokenization
- ▶ Avoid String Processing
- ▶ Recognize Tail Recursion
- ▶ Let Indexing Help
- ▶ Use Accumulators
- ▶ Use Difference Lists

Narrow the Search

Efficient programs must search efficiently.

Example

Knowledge base contains 1000 grey objects and 10 horses.

?- horse(X), grey(X).

is 100 times as fast as

?- grey(X), horse(X).

Narrow the search space as early as possible.

Narrow the Search

Example

Determine whether two lists are equal as sets.

Bad solution:

```
set_equal(L1,L2) :- permute(L1,L2).
```

N element list has $N!$ permutations.

Testing set-equality of 20-element list can require 2.4×10^{18} comparisons.

Better solution:

```
set_equal(L1,L2) :- sort(L1,L3), sort(L2,L3).
```

N -element list can be sorted in $N \log N$ steps. Faster than the first solution by a factor of more than 10^{16} .

Let Unification do the Work

Example

Write a predicate that accepts a list and succeeds if the list has three elements.

Bad solution:

```
had_three_elements(L) :- length(L, N), N=3.
```

Slightly better solution:

```
had_three_elements(L) :- length(L, 3).
```

Good solution:

```
had_three_elements([_, _, _]).
```

Let Unification do the Work

Example

Write a predicate that accepts a list and generates from it a similar list with the first two elements swapped.

Good solution:

```
swap_first_two([A,B|Rest],[B,A|Rest]).
```

The data structures `[A,B|Rest]` and `[B,A|Rest]`, or templates for them, are created when the program is compiled, and unification gives values to the variables at run time.

Avoid `assert` and `retract`

Reasons:

- ▶ `assert` and `retract` are relatively slow and they lead to a messy logic.
- ▶ In many implementations the dynamic predicates can not run in a full compiled speed.
- ▶ The effect of `assert` and `retract` can not be undone by backtracking.
- ▶ Programs get hard to debug.

Avoid `assert` and `retract`

Legitimate Uses:

- ▶ To record new knowledge in the knowledge base.
- ▶ To store the intermediate results of a computation that *must* backtrack past the point at which it gets its result. (Think about using `setof` or `bagof` instead. It might be faster.)

Understand Tokenization

Fundamental unit: Term (numbers, atoms, structures).

- ▶ Numbers are stored in fixed-point or floating-point binary.
- ▶ Atoms are stored in a symbol table in which each atom occurs only once.
- ▶ Atoms in the program are replaced by their addresses in the symbol table (tokenization).

Understand Tokenization

- ▶ Because of tokenization the structure

```
f('What a long atom this seems to be',  
  'What a long atom this seems to be',  
  'What a long atom this seems to be')
```

is more compact than

```
g('aaaaa', 'bbbbbb', 'cccccc') .
```

- ▶ To compare two atoms, even long ones, the computer needs only compare their addresses.
- ▶ By contrast, comparing lists or structures requires every element to be examined individually.

Avoid String Processing

Strings:

- ▶ Lists of numbers representing ASCII codes of characters.
- ▶ `abc` – an atom.
- ▶ `"abc"` – a list `[97, 98, 99]`.
- ▶ Strings are designed to be easily taken apart.
- ▶ Their only proper use is in situations where access to the individual characters is essential.

Recognize Tail Recursion

Recursion:

- ▶ Can be inefficient.
- ▶ Each procedure call requires information to be saved so that control can return to the calling procedure.
- ▶ If a clause calls itself 1000 times, there will be 1000 copies of its stack frame in memory.

Exception:

- ▶ Tail Recursion.
- ▶ Control need not return to the calling procedure because there is nothing more for it to do.

Recognize Tail Recursion

Tail recursion exists when:

- ▶ The recursive call is the last subgoal in the clause, and
- ▶ There are no untried alternative clauses, and
- ▶ There are no untried alternatives for any subgoal preceding the recursive call in the same clause.

Recognize Tail Recursion

Example

This predicate is tail recursive.

```
test1 :- write(hello), nl, test1.
```

Example

This predicate is **not** tail recursive because the recursive call is not last.

```
test2 :- test2, write(hello), nl.
```

Recognize Tail Recursion

Example

This predicate is **not** tail recursive because it has an untried alternative.

```
test3:- write(hello), nl, test3.  
test3:- write(goodbye).
```

Recognize Tail Recursion

Example

This predicate is **not** tail recursive because a subgoal has an untried alternative.

```
test4:- g, write(hello), nl, test4.  
       g:- write(starting).  
       g:- write(beginning).
```


Let Indexing Help

To match the query

$?- f(a, b).$

PROLOG does **not** look at all the clauses in the knowledge base.

It looks only the clauses for f .

Indexing.

Let Indexing Help

Implementation dependent.

- ▶ Many implementations index not only the predicate symbol but also the main functor of the first argument
- ▶ *First-argument indexing.*
- ▶ For $?- f(a, b)$.
The search considers only clauses that match $f(a, \dots)$ and neglects clauses such as $f(b, c)$.

Let Indexing Help

Consequences of (first-argument) indexing.

Argument order:

- ▶ The first argument should be the one most likely to be known at search time, and
- ▶ Preferably the most diverse.
- ▶ Better to have

$f(a, x)$.

$f(b, x)$.

$f(c, x)$.

than

$f(x, a)$.

$f(x, b)$.

$f(x, c)$.

Let Indexing Help

Consequences of (first-argument) indexing.

Indexing can make a predicate tail recursive when it otherwise would not be.

Example

$$p(f(A, B)) \text{ :- } p(A) .$$
$$p(a) .$$

is tail-recursive because indexing eliminates $p(a)$ from consideration.