

Programming Language Concepts: Lecture 23

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Quicksort in Prolog

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% quicksort(Xs, Ys) :- Ys is a sorted permutation of Xs
quicksort([], []).
quicksort([X | Xs], Ys) :-
    partition(X, Xs, Littles, Bigs),
    quicksort(Littles, Ls),
    quicksort(Bigs, Bs),
    append(Ls, [X | Bs], Ys).
```

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```

where

```
% partition(X, Xs, Ls, Bs) :-
%       Ls : list of elements of Xs that are < X
%       Bs : list of elements of Xs that are >= X
partition(_, [], [], []).
partition(X, [Y | Xs], [Y | Ls], Bs) :-
    X > Y, partition(X, Xs, Ls, Bs).
partition(X, [Y | Xs], Ls, [Y | Bs]) :-
    X <= Y, partition(X, Xs, Ls, Bs).
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- ▶ Consider `?- partition(7,[9,8,1,5],Ls,Bs).`

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```

- ▶ Consider `?- partition(7,[9,8,1,5],Ls,Bs).`
- ▶ `append(Ls, [X | Bs], Ys).`
 - ▶ As in functional programming, complexity of `append` is proportional to length of `Ls`
 - ▶ Can this be avoided?

Backtracking in Prolog

Consider rules

```
G :- P1,P2,P3.
```

```
G :- P4,P5,P6.
```

- ▶ First try G.
 - ▶ If P3 fails, backtrack and retry P2.

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 - ▶ If **P2** fails, backtrack and retry **P1**.

Backtracking in Prolog

Consider rules

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G :- P1,P2,P3.
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G :- P4,P5,P6.
```

- ▶ First try **G**.
 - ▶ If **P3** fails, backtrack and retry **P2**.
 - ▶ If **P2** fails, backtrack and retry **P1**.
 - ▶ If **P1** fails, try second rule.
- ▶ Second rule is tried after all possible ways of satisfying first rule fail.

Backtracking in Prolog ...

Goal $p(X)$, rules of the form `if B then S else T`

```
p(x) :- B,S.
```

```
p(X) :- not B, T.
```

- ▶ `not B` succeeds if `B` fails.
- ▶ Can we avoid recomputing `B`?

Cut

- Special goal `!`, called `cut`

`p(x) :- B, !, S.`

`p(x) :- T.`

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 $p(x) \text{ :- } T.$

- ▶ $!$ always succeeds
- ▶ Discard alternative ways of computing B
- ▶ Discard second rule $p(x) \text{ :- } T.$

More generally, if we have

$p(s_1) \text{ :- } A_1 .$
 \vdots
 $p(s_i) \text{ :- } B, !, C.$
 \vdots
 $p(s_k) \text{ :- } A_k .$

B is not retried and clauses $i+1$ to k are discarded.

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partition(_, [], [], []).  
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Control structures

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for(N,G) :- N > 0, call(G), M is N-1, for(M,G),!.
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```
if_then_else(B, S, T) :- call(B),!,call(S).
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if_then_else(B, S, T) :- call(T).
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```

```
if_then_else(B, S, T) :- call(B),!,call(S).  
if_then_else(B, S, T) :- call(T).
```

Use with care. Destroys declarative structure!

Control structures

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```
not(G) :- call(G),!,fail  
not(_).
```

- ▶ Use `not` with care
- ▶ To generate all members of a list that are not 1
 - ▶ `member(X, Ls), not(X = 1).`
 - ▶ `not(X = 1), member(X, Ls).`

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- ▶ Should only use `not` when term is already instantiated

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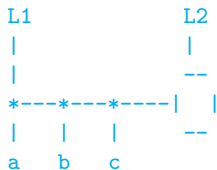
- ▶ `member(X, Ls), not(X = 1).` ✓
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- ▶ Should only use `not` when term is already instantiated

```
?- not(X = 1).
no
```

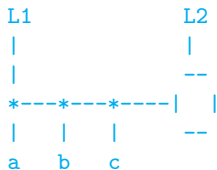
Difference lists

- Represent a list in terms of **front** and **back**



Difference lists

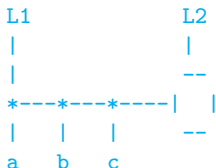
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Difference lists

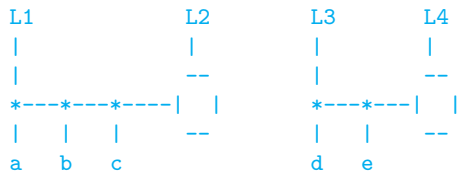
- Represent a list in terms of **front** and **back**



- Unify **L1** with $[a, b, c | Z]$ and **L2** with **Z**
- **L2** points to a “hole” that can be instantiated by another term

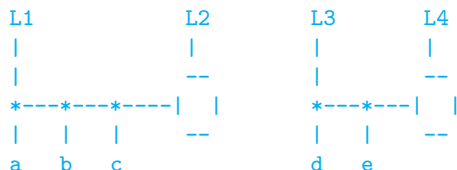
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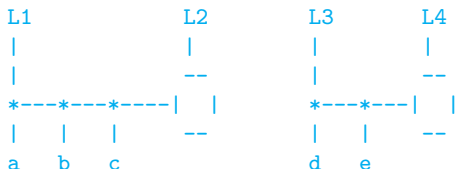
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- `app(L1,L2,L3,L4,X,Y)` succeeds when difference lists `(L1,L2)` and `(L3,L4)` combine to form difference list `(X,Y)`

Difference lists ...

- ▶ Suppose we want to append L1 and L3



- ▶ `app(L1,L2,L3,L4,X,Y)` succeeds when difference lists $(L1,L2)$ and $(L3,L4)$ combine to form difference list (X,Y)
- ▶ Single goal
`app(L1,L2,L2,L4,L1,L4) .`
- ▶ Normally, difference lists are denoted $L1-L2$.
- ▶ If X is a difference list, unify with $Y-[]$ to rectify it

Flatten

- ▶ Flatten an arbitrarily nested list into an linear list

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```
flatten(X,Y) :- flatpair(X,Y-[]).
```

```
flatpair([],L-L).
```

```
flatpair([H,T],L1-L3) :- flatpair(H,L1-L2), flatpair(T,L2-L3).
```

```
flatpair(X,[X|Z]-Z).
```