CSE 341:
Programming Languages

Spring 2006

Lecture 6 — More on Tail Recursion & Accumulators

Implementing lists

Want: null, hd, tl, ::

How: Arrays? Pointers? Other?

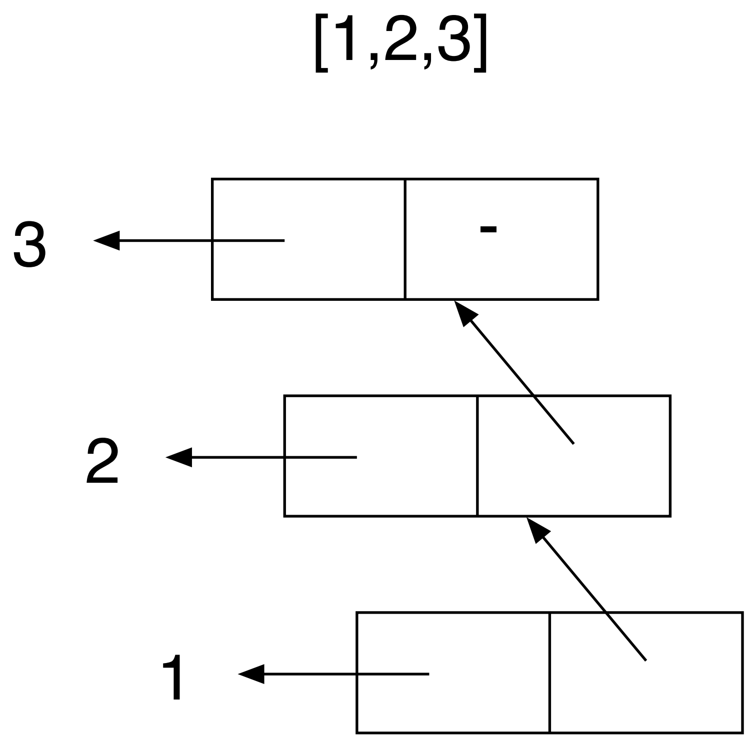
Costs: memory, time, code

Implementing lists

Want: null, hd, tl, ::

How: Arrays? Pointers? Other?

Costs: memory, time, code



Using Lists (Java)

Consider a linked list of integers, implemented in Java.

How would you implement functions for:

- Finding the *length* of a list
- Finding the *last element* of a list

Using Lists (ML)

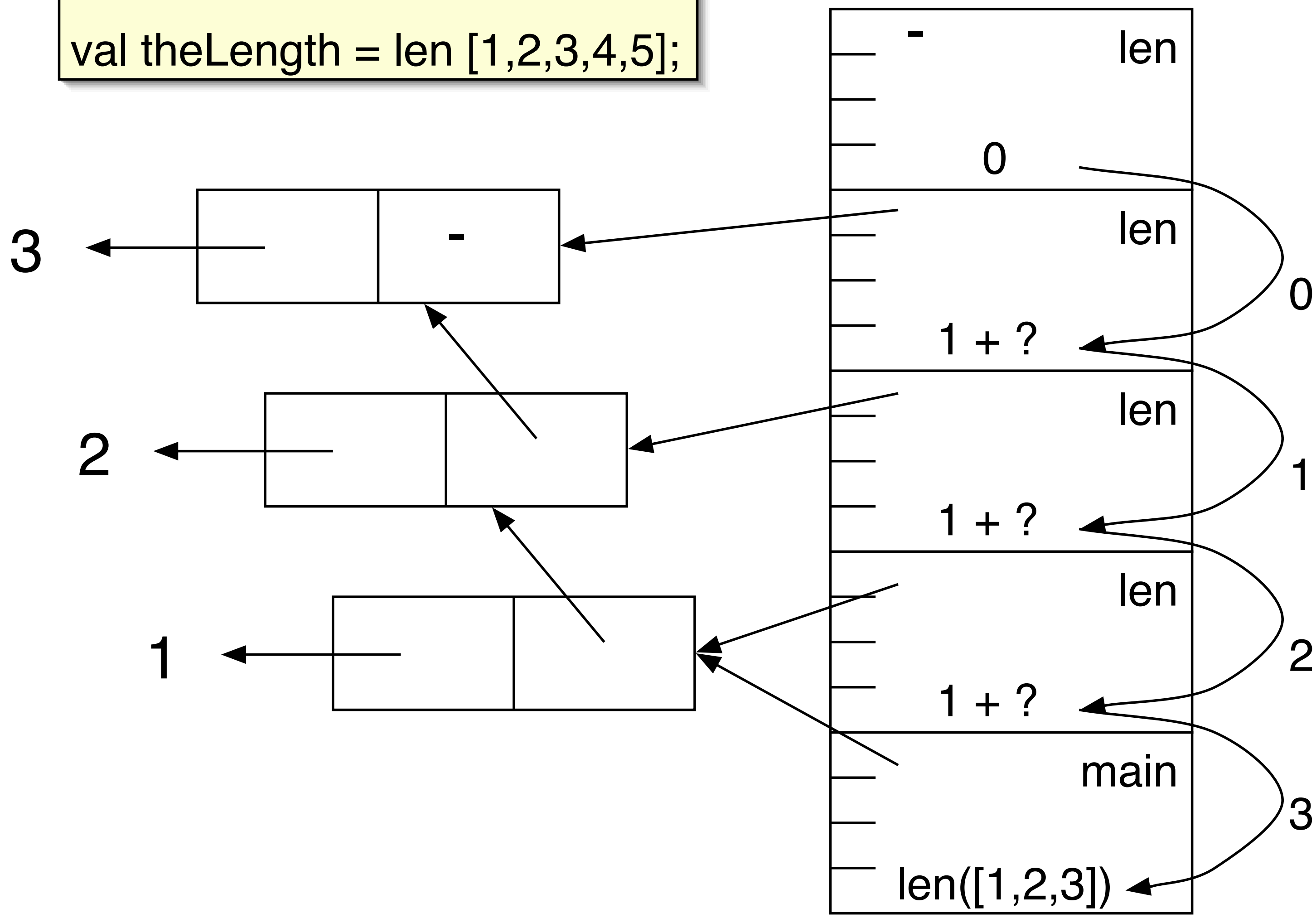
Consider

```
fun len []       = 0
|   len (x::xs) = 1 + len xs;

val theLength = len [1,2,3,4,5];
```

Q: How do you implement function call?

A: A “Call Stack”

```
fun len []      = 0
  |  len (x::xs) = 1 + len xs;

val theLength = len [1,2,3,4,5];
```



Implementing calls

Consider

```
fun len []       = 0
|   len (x::xs) = 1 + len xs;

val theLength = len [1,2,3,4,5];
```

Compare:

```
fun last  [x]   = x
|   last(x::xs) = last xs;

val theLast = last [1,2,3,4,5];
```

Tail calls

If the result of `f(x)` is the result of the enclosing function body, then `f(x)` is a *tail call*.

More precisely, a tail call is a call in *tail position*:

- In `fun f(x) = e`, `e` is in tail position.
- If `if e1 then e2 else e3` is in tail position, then `e2` and `e3` are in tail position (not `e1`). (Similar for case).
- If `let b1 ... bn in e end` is in tail position, then `e` is in tail position (not any binding expressions).
- Function arguments are not in tail position.
- ...

So what?

Why does this matter?

- Implementation takes space proportional to depth of function calls ("call stack" must "remember what to do next")
- But in functional languages, implementation must ensure tail calls eliminate the caller's space
- Accumulators are a systematic way to make some functions tail recursive
- "Self" tail-recursive is very loop-like because space does not grow.