Room Change, OH & Travel

Fri. 5/19 only, we will meet in THO 125 (at usual time)

My Office Hour: Fridays at ?

But not this week—out of town. (Guest Lectures by Jonah W & F.)
Where we are

Two implementation tidbits: call stack & cons cells

Tail recursion avoids call stack overhead

Accumulator-style recursion typically tail-recursive

Today:

- more tail/accumulator examples
- more on pattern-matching as an elegant generalization of variable binding.
- first-class functions (closures, functions as values)
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 \( \text{fun } f(x) = e \), \( e \) is in tail position.
- If \( \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \) is in tail position, then \( e_2 \) and \( e_3 \) are in tail position (not \( e_1 \)). (Similar for case).
- If \( \text{let } b_1 \ldots b_n \text{ in } e \text{ end} \) 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.
fun rev1(nil) = nil
| rev1(x::xs) = rev1(xs) @ [x];

Run time?
fun rev1(nil) = nil
   | rev1(x::xs) = rev1(xs) @ [x];

Run time?

$O(n^2)$!

L1 @ L2 must copy L1:

fun append([],l2) = l2
   | append(x::xs,l2) = x::append(xs,l2);

So rev1([1,2,...,n]) takes time
$1 + 2 + \cdots + n = O(n^2)$. 
fun rev1(nil) = nil
  |
  rev1(x::xs) = rev1(xs) @ [x];

fun rev2 lst =
  let fun f (nil, acc) = acc
      |
      f (x::xs, acc) = f(xs,x::acc)
      in
      f(lst,nil)
      end

The standard trick: instead of operating on recursive result, push operation into the recursive call.

Run time?
Deep patterns

Patterns are much richer than we have let on. A pattern can be:

- A variable (matches everything, introduces a binding)
- _ (matches everything, no binding)
- A constructor and a pattern (e.g., \texttt{C p}) (matches a value if the value “is a C” and \texttt{p} matches the value it carries)
- A pair of patterns (\( (p_1, p_2) \)) (matches a pair if \( p_1 \) matches the first component and \( p_2 \) matches the second component)
- A record pattern...
- An integer constant...
- ...

CSE 341 Spring 2006, Lecture 7
The truth, the whole truth, and nothing but

It's really:

- `val p = e`
- `fun f p1 = e1 | f p2 = e2 ... | f pn = en`
- `case e of p1 => e1 | ... | pn => en`

Inexhaustive matches may raise exceptions and are bad style.

Example: could write `Rope pr` or `Rope (r1,r2)`

Fact: Every ML function takes exactly one argument!
Some function examples

- fun f1 () = 34
- fun f2 (x,y) = x + y
- fun f3 pr = let val (x,y) = pr in x + y end

Is there any difference to callers between f2 and f3?

In most languages, “argument lists” are syntactically separate, *second-class* constructs.

Can be useful: f2 (if e1 then (3,2) else pr)