CSE 341:
Programming Languages

Spring 2007

Lecture 3 — Lists, Let bindings, options

Lists

We can have pairs of pairs of pairs... but we still "commit" to the amount of data when we write down a type.

Lists can have *any* number of elements:

- `[]` is the empty list (a value)
- More generally, `[v1,v2,...,vn]` is a length n list
- If `e1` evaluates to `v` and `e2` evaluates to a list `[v1,v2,...,vn]`, then `e1::e2` evaluates to `[v,v1,v2,...,vn]` (a value).
- `null e` evaluates to true if and only if `e` evaluates to `[]`
- If `e` evaluates to `[v1,v2,...,vn]`, then `hd e` evaluates to `v1` and `tl e` evaluates to `[v2,...,vn]`.
  - If `e` evaluates to `[]`, both `hd e` and `tl e` raise *run-time exceptions*. (Different from type errors; more on this later.)

List types

A given list's elements must all have the same type.

If the elements have type `t`, then the list has type `t list`. Examples: `int list`, `(int*int) list`, `(int list) list`.

What are the type rules for `::`, `null`, `hd`, and `tl`?

- Possible exceptions do not affect the type.

Hmmm, that does not explain the type of `[]` ?

- It can have any list type, which is indicated via `'a list`.
- That is, we can build a list of any type from `[]`.
- *Polymorphic* types are 3 weeks ahead of us.
  - Teaser: `null`, `hd`, and `tl` are not keywords!

Recursion again

Functions over lists that depend on all list elements will be recursive:

- What should the answer be for the empty list?
- What should they do for a non-empty list? (In terms of answer for the tail of the list.)

Functions that produce lists of (potentially) any size will be recursive:

- When do we create a small (e.g., empty) list?
- How should we build a bigger list out of a smaller one?

Let bindings

Motivation: Functions without local variables can be poor style and/or really inefficient.

Syntax: `let b1 b2 ... bn in e end` where each `bi` is a *binding*.

Typing rules: Type-check each `bi` and `e` in context including previous bindings. Type of whole expression is type of `e`.

Evaluation rules: Evaluate each `bi` and `e` in environment including previous bindings. Value of whole expression is result of evaluating `e`.

Elegant design worth repeating:

- Let-expressions can appear anywhere an expression can.
- Let-expressions can have any kind of binding.
  - Local functions can refer to any bindings *in scope*.

More than style

Exercise: hand-evaluate `bad_max` and `good_max` for lists `[1,2]` `[1,2,3]`, and `[3,2,1]`.

Extra Credit Exercise: As a function of n, how long will it take to calculate

- `bad_max([1, 2, ..., n])`?
- `bad_max([n, n-1, ..., 1])`?

Summary and general pattern

Major progress: recursive functions, pairs, lists, let-expressions

Each has a syntax, typing rules, evaluation rules.

Functions, pairs, and lists are very different, but we can describe them in the same way:

- How do you create values? (function definition, pair expressions, empty-list and `::`)
- How do you use values? (function application, `#1` and `#2`, `null`, `hd`, and `tl`)

This (and conditionals) is enough for your homework though:

- `andalso` and `orelse` help
- You need *options* (next slide)
- Soon: much better ways to use pairs and lists (pattern-matching)

Options

"Options are like lists that can have at most one element."

- Create a `t option` with `NONE` or `SOME e` where `e` has type `t`.
- Use a `t option` with `isSome` and `valOf`

Why not just use (more general) lists? An interesting style trade-off:

- Options better express purpose, enforce invariants on callers, maybe faster.
- But cannot use functions for lists already written.