CSE 341: Programming Languages

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Lecture 7—Motivation and First-Class Functions
Today

- Finish course motivation
- Summarize what we’ve learned with a concise and well-known notation for recursively-defined language constructs
- Begin first-class functions
Why these 3?

*Functional programming* (ML, Scheme) encourages recursion, discourages mutation, provides elegant, lightweight support for first-class code. Support for extensibility complements OO.

- ML has a polymorphic type system (vindication imminent!) complementary to OO-style subtyping, a rich module system for abstract types, and rich pattern-matching.

- Scheme has dynamic typing, “good” macros, fascinating control operators, and a minimalist design.

- Smalltalk has classes but not types, an unconventional environment, and a complete commitment to OO.

Runners-up: Haskell (laziness and purity), Prolog (unification and backtracking), thousands of others...
Why not some popular ones?

- Java: you know it, will contrast at end of course (e.g., interfaces, anonymous inner classes, container types)
- C: lots of “implementation-dependent” behavior (a bad property), and we have CSE303
- C++: an enormous language, and unsafe like C
- Perl: advantages (strings, files, ...) not foci of this course. Python or Ruby would be closer.
Are these useful?

The way we use ML/Scheme/Smalltalk in 341 can make them seem almost “silly” precisely because we focus on interesting language concepts.

“Real” programming needs file I/O, strings, floating-point, graphics libraries, project managers, unit testers, threads, foreign-function interfaces, ...

- These languages have all that and more!
- If Java were in 341, it would seem “silly” too

Somewhat outdated links:

- OCaml: http://caml.inria.fr/users_programs-eng.html
Summary and Some Notation

Learned the syntax, typing rules, and semantics for (a big) part of ML

Can summarize *abstract syntax* with *(E)BNF*. Informally:

\[
\begin{align*}
  t &::= \text{int} \mid \text{bool} \mid \text{unit} \mid \text{dtname} \\
  &\quad \mid t_1 \rightarrow t_2 \mid t_1 \ast t_2 \mid \{x_1=t_1, \ldots, x_n=t_n\} \\
  e &::= 34 \mid x \mid (e_1,e_2) \mid \text{if } e_1 \text{ then } e_2 \text{ else } e_3 \\
  &\quad \mid \text{let } b_1 \ldots b_n \text{ in } e \text{ end} \mid e_1 \ e_2 \\
  &\quad \mid \text{case } e \text{ of } p_1 \Rightarrow e_1 \mid \ldots \mid p_n \Rightarrow e_n \\
  &\quad \mid e_1 + e_2 \mid \{x_1=e_1, \ldots, x_n=e_n\} \mid C \ e \\
  b &::= \text{val } p = e \mid \text{fun } f \ p = e \\
  &\quad \mid \text{datatype } \text{dtname} = \text{C1 of } t_1 \mid \ldots \mid \text{Cn of } t_n \\
  p &::= 34 \mid x \mid _{} \mid C \ p \mid (p_1,p_2) \mid \{x_1=p_1, \ldots, x_n=p_n\}
\end{align*}
\]

Things left out of this grammar: *n*-tuples, field-accessors, floating-point, boolean constants, and/or/orelse, lists, ...
First-Class Functions

- Functions are values. (Variables in the environment are bound to them.)

- We can pass functions to other functions.
  - *Factor* common parts and *abstract* different parts.

- Most polymorphic functions take functions as arguments.
  - Non-example: `fun f x = 42`

- Some functions taking functions are polymorphic.
Type Inference and Polymorphism

ML can infer function types based on function bodies. Possibilities:

- The argument/result must be one specific type.
- The argument/result can be any type, but may have to be the same type as other parts of argument/result.
- Some hand-waving about “equality types”

We will study this parametric polymorphism more later.

Without it, ML would be a pain (e.g., a different list library for every list-element type).

Fascinating: If \( f : \text{int} \rightarrow \text{int} \), there are lots of values \( f \) could return. If \( f : \text{'a} \rightarrow \text{'a} \), whenever \( f \) returns, it returns its argument!
Anonymous Functions

As usual, we can write functions anywhere we write expressions.

• We already could:

\[
\text{(let fun f x = e in f end)}
\]

• Here is a more concise way (better style when possible):

\[
\text{(fn x => e)}
\]

• Cannot do this for recursive functions (why?)
Returning Functions

Syntax note: \(\to\) “associates to the right”

- \(t_1\to t_2\to t_3\) means \(t_1\to(t_2\to t_3)\)

Again, there is nothing new here.

The key question: What about free variables in a function value? What \textit{environment} do we use to evaluate them?

Are such free variables useful?

You must understand the answers to move beyond being a novice programmer.