

COMP 210, FALL 2000

Lecture 19: Functional Abstraction

Reminders:

1. Next exam is a take-home; handed out 10/20/2000, due 10/27/00 (5pm).
2. Homework will be due next Friday.
3. Review session? (at most one)

Review

1. Last class: rewriting rules for **local**, other uses for **local**.

On to Functional Abstraction

Write a simple function that consumes a list of numbers and produces a list of numbers. The numbers in the returned list should be exactly those numbers in the original list that are less than 5 (in the same order as the original list).

```
;; keep-lt-5 : list of numbers -> list of numbers
;; Purpose: keeps all input numbers less than 5
(define (keep-lt-5 alon)
  (cond
    [(empty? alon) empty]
    [(cons? alon)
     (cond
       [(< (first alon) 5)
        (cons (first alon) (keep-lt-5 (rest alon)))]
       [else (keep-lt-5 (rest alon))])])
  ))
```

What about keep-lt-9 ?

```
;; keep-lt-9 : list of numbers -> list of numbers
;; Purpose: keeps all input numbers less than 9
(define (keep-lt-9 a-lon)
  (cond
    [(empty? alon) empty]
    [(cons? alon)
     (cond
       [(< (first alon) 9)
        (cons (first alon) (keep-lt-9 (rest alon)))]
       [else (keep-lt-9 (rest alon))] ) ] ))
```

Notice how much these two functions have in common. Can we write one function that captures all this common code (*single-point of control*) and use it to implement `keep-lt-5` and `keep-lt-9`?

```
;; keep-lt: number list-of-numbers -> list-of-numbers
;; Purpose: keep all input numbers that are less than the given number
(define (keep-lt num alon)
  (cond
    [(empty? alon) empty]
    [(cons? alon)
     (cond
       [< (first alon) num]
       (cons (first alon) (keep-lt num (rest alon)))]
       [else (keep-lt num (rest alon))] ) ] ))
```

Notice that **num** never changes. We could use a local to avoid passing it around in so many places (and save work) [But, efficiency is only a concern in the 1st part of Comp 210 when it becomes an exponential problem.]

```
;; keep-lt: number list-of-numbers -> list-of-numbers
;; Purpose: keep all input numbers that are less than the given number
(define (keep-lt num alon)
  (local
    [(define (filter-lt alon)
      (cond
        [(empty? alon) empty]
        [(cons? alon)
         (cond
           [< (first alon) num]
           (cons (first alon) (filter-lt (rest alon)))]
           [else (filter-lt (rest alon))] ) ] ))
    ]
    (filter-lt alon)
  ))
```

Using keep-lt, we can define keep-lt-5 and keep-lt-9

```
(define (keep-lt-5 alon)
  (keep-lt 5 alon))

(define (keep-lt-9 alon)
  (keep-lt 9 alon))
```

What if we wanted to write keep-gt-5

```
;; keep-gt-5 : list of numbers -> list of numbers
;; Purpose: keeps all input numbers greater than 5
(define (keep-gt-5 alon)
  (cond
    [(empty? alon) empty]
    [(cons? alon)
     (cond
       [(> (first alon) 5)
        (cons (first alon) (keep-gt-5 (rest alon)))]
       [else (keep-gt-5 (rest alon))])])
  ))
```

Where do these functions differ? Only in the comparison operator and in the names of the functions. [The last lecture should have convinced you that the names are malleable.]

How can we reuse the common code here? Previously, we made the upper limit on the value into a parameter. Now, we need to make the comparison operation itself be a parameter. Can we pass in the comparison operator?

Critical Aside

How do we represent > in the contract? (number number -> number)
We've been writing these contracts for eight weeks now. This should be pretty natural.

Back To Abstracting Out Comparison

;; keep-rel-5 : (num num -> bool) list of numbers -> list of numbers

;; Purpose: keeps all input numbers that have relation than 5

```
(define (keep-rel-5 relation alon)
  (cond
    [(empty? alon) empty]
    [(cons? alon)
     (cond
       [(relation (first alon) 5)
        (cons (first alon) (keep-rel-5 relation (rest alon)))]
       [else (keep-rel-5 (rest alon))])])
  ))
```

and

```
(define (keep-lt-5 alon)
  (keep-rel-5 < alon))

(define (keep-gt-5 alon)
  (keep-rel-5 > alon))
```

As before, we can use local in the obvious way to avoid passing relation as a parameter.

;; keep-rel-5 : (num num -> bool) list of numbers -> list of numbers

;; Purpose: keeps all input numbers that have relation than 5

```
(define (keep-rel-5 relation alon)
  (local
    [(define (filter-rel alon)
      (cond
        [(empty? alon) empty]
        [(cons? alon)
         (cond
           [(relation (first alon) 5)
            (cons (first alon) (filter-rel (rest alon)))]
           [else (filter-rel (rest alon))])])])
    (filter-rel alon)))

(define (keep-lt-5 alon)
  (keep-rel-5 < alon))
```

Of course, the next thing we want to do is abstract out the number 5. We should be able to write a function that takes both the relation and the limit as parameters and returns a list containing the specified subset of the numbers in the original list.

```
;; keep-rel (num num -> bool) num list-of-nums -> list-of-nums
;; Purpose: keep all the numbers in the input list that have the relation
given
;; by the function argument to the number argument (whew!)
(define (keep-rel relation num alon)
  (local [(define filter-rel alon) ;; treat relation & num as invariant
          (cond
            [(empty? alon) empty]
            [(cons? alon)
             (cond
               [(relation (first alon) num)
                (cons (first alon) (filter-rel (rest alon)))]
               [else (filter-rel (rest alon))] ) ] )
          ]
    (filter-rel alon) ))
(define (keep-gt-9 alon)
  (keep-rel > 9 alon))
```

Programs as Values

How can we pass $>$ or $<$ or $=$ as an argument (parameter) to a function such as `keep-rel` ?

A program is just another value. Recall that we created test values using the `define` operation. We used it to create numbers and lists. These became named values in the world of Scheme values. We use the same syntax and operation to create programs, don't we? The `define` operator takes its two parts – the function name and argument list and its body. The way that DrScheme evaluates the function is a little more complex than evaluating `(define Seventeen 17)` because it involves rewriting the parameters with their values. Of course, `Seventeen` has no parameters, so the mechanism for handling functions will work on a defined numerical value as a trivial case.

In general, functions (programs) are values. We can use them anywhere that we use values. For example, we can build lists of functions, just as we build lists of symbols or numbers, or objects created with `define-struct`.

What about $>$? Isn't it special? Isn't it a built-in operator?

Yes. It is a built-in operator, but that grants it no special exemptions from the rules that govern the execution of Scheme programs. The built-in operators are just functions themselves. Thus, $+$, $*$, $/$, $-$, $<$, $=$, $>$ are all programs that you could write. So are `add1`, `sub1`. **BUT**, `define` and `define-struct` are not implemented that way; they are only valid in the definitions window—not in the interactions window. That gives you a hint that they are not Scheme operators.

What about returning a program? If we can treat programs as values, can we write a Scheme program that creates new programs and returns them?

Yes. However, we have not (yet) seen an operator that builds a program. That's in next Friday's lecture. With the right operator, `lambda`, you can write programs that create new programs and return them.