More Procedures

CSE 413, Autumn 2005

Programming Languages

http://www.cs.washington.edu/education/courses/413/05au/

References

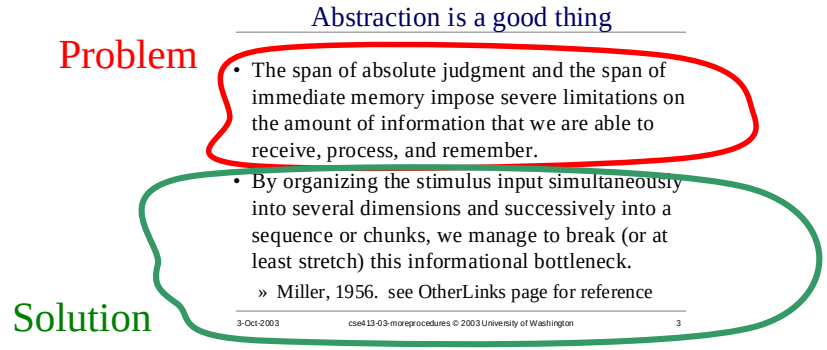
- Sections 1.2-1.2.2, *Structure and Interpretation of Computer Programs*

Abstraction is a good thing

- The span of absolute judgment and the span of immediate memory impose severe limitations on the amount of information that we are able to receive, process, and remember.
- By organizing the stimulus input simultaneously into several dimensions and successively into a sequence or chunks, we manage to break (or at least stretch) this informational bottleneck.
  - » Miller, 1956. see OtherLinks page for reference

"We can only deal with a few things at once, so blobify the problem." DWJ

For example ...



A clean abstraction is a good thing

- One of the interesting and difficult things about software design is deciding how to chop up the system design in a "logical" fashion
- "Common sense" design is not always obvious
- Two useful goals
  - » Increase Cohesion
  - » Decrease Coupling

Cohesion and Coupling

- Cohesion describes the degree to which the various parts of a single conceptual object relate to one another in a logical way
  - » a "cohesive design" is a good thing
- Coupling describes the degree to which different conceptual objects are tied together through implementation details and assumptions
  - » a "highly coupled design" is a bad thing

Name space pollution

- One common problem that contributes to coupling between modules is naming
- As much as possible, you want to keep the details of your implementation from leaking out into the outside world
  - » reduce conflict with other modules and reduce the complexity of your own design
  - » make it possible to replace your implementation entirely with a new one that has the same external interface but completely different internals

Procedure names

- Recall that sqrta.scm defined a number of small auxiliary procedures to accomplish the task of calculating the square root
  - » sqrt-iter, good-enough?, improve
- None of these procedures are of specific interest to the outside world
  - » they interfere with other designs that want to build other procedures with the same names
  - » the prefix "sqrt-" is clutter in our own design

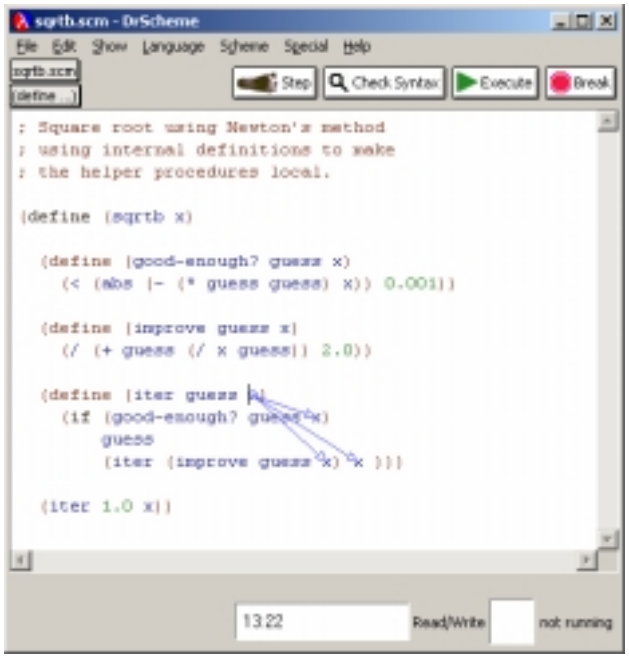
Helper definitions local to procedure

```
(define (sqrtb x)

  (define (good-enough? guess x)
    (< (abs (- (* guess guess) x)) 0.001))

  (define (improve guess x)
    (/ (+ guess (/ x guess)) 2.0))

  (define (iter guess x)
    (if (good-enough? guess x)
        guess
        (iter (improve guess x) x )))

  (iter 1.0 x))
```

```
; Square root using Newton's method
; using internal definitions to make
; the helper procedures local.
```


Local names

- The names of the helper procedures are now local to the define statement for sqrt
- The *scope* of the names is the define block
- Notice that the scope of the names of the formal parameters of each local procedure is the body of that procedure
  - » *the parameter names of a procedure are local to the body of the procedure*



Parameter names are local

```
(define (sqrtc x)

  (define (good-enough? ga xa)
    (< (abs (- (* ga ga) xa)) 0.001))

  (define (improve gb xb)
    (/ (+ gb (/ xb gb)) 2.0))

  (define (iter gc xc)
    (if (good-enough? gc xc)
        gc
        (iter (improve gc xc) xc )))

  (iter 1.0 x))
```

```
; Square root using Newton's method
; using internal definitions to make
; the helper procedures local.

; Replaced guess and x with ga, gb,
; gc and xa, xb, xc to highlight the fact
; that they are not all the same object.
```

Note that "x" is defined in the outer block and so it is visible to all of the helper procedures.

Do we need to pass x around from procedure to procedure?

Refer to variables in enclosing scope

```
(define (sqrtc x)

  (define (good-enough? ga xa)
    (< (abs (- (* ga ga) xa)) 0.001))

  (define (improve gb xb)
    (/ (+ gb (/ xb gb)) 2.0))

  (define (iter gc xc)
    (if (good-enough? gc xc)
        gc
        (iter (improve gc xc) xc )))

  (iter 1.0 x))
```

- xa is supplied to good-enough? as a parameter.
- The value of that parameter is always "x".
- Therefore, we don't need to pass it as a parameter to procedure good-enough?.

- xb is supplied to improve as a parameter.
- The value of that parameter is always "x".
- Therefore, we don't need to pass it as a parameter to procedure improve.

- xc is supplied to iter as a parameter.
- The value of that parameter is "x".
- iter calls itself recursively, and supplies the same value of "x" that it was given.
- Therefore, the value of "xc" is always "x", and we don't need to pass it as a parameter to procedure iter.

All x parameters replaced with global x

```
(define (sqrtd x)

  (define (good-enough? ga)
    (< (abs (- (* ga ga) x)) 0.001))

  (define (improve gb)
    (/ (+ gb (/ x gb)) 2.0))

  (define (iter gc)
    (if (good-enough? gc)
        gc
        (iter (improve gc))))

  (iter 1.0))
```

```
; Square root using Newton's method.
; Removed all the x parameters since they
; refer to the globally available x in
; every case.
```


Lexical scoping

- The preceding changes to the sqrt definition are examples of the use of *lexical scoping*
- Free variables (those that are not bound by the parameter list or a local define) are taken to refer to bindings made by enclosing procedure definitions
- The bindings are looked up in the environment in which the procedure was *defined*

Recursion and Iteration

- Definitions
  - » procedure (the text definition)
  - » process (the actual live action events)
- A recursive procedure (one that calls itself) does not necessarily generate a recursive process (one that has an open deferred operations remaining for each call)
- Many languages make the two always equivalent, but it is not necessary

Two implementations of factorial

```
; linear recursive

(define (facta n)
  (if (= n 1)
      1
      (* n (facta (- n 1)))))

; iterative

(define (factb n)
  (define (iter prod count)
    (if (> count n)
        prod
        (iter (* count prod) (+ count 1))))
  (iter 1 1))
```

We don't know what (facta (- n 1)) is until we have worked our way all the way down to facta(1). All the multiplications are deferred operations.

We are counting up. We know what 1*1 is, and we know what 1+1 is. So we can go directly from (iter 1 1) to (iter 1 2) to (iter 2 3) to (iter 6 4) etc.

Difference

- The key difference between the linear recursive process and the iterative process is this
  - » recursive - there are operations not yet completed which must be remembered by the system running the program - generally on a stack
  - » iterative - all of the state for the block of code can be captured in a finite set of variables - these variables are the arguments to the iterating function

Two implementations of simple counter

```
(define (print x)
  (display x))

; iterative process

(define (count1 x)
  (cond ((= x 0) (print x))
        (else (print x)
              (count1 (- x 1)))))

; linear recursive process

(define (count2 x)
  (cond ((= x 0) (print x))
        (else (count2 (- x 1))
              (print x))))
```

```
> (count1 4)
43210
> (count2 4)
01234
>
```

why?