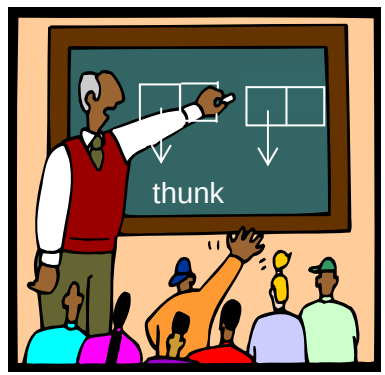
6.001 recitation 20 5/2/07

- lazy eval
- streams



Dr. Kimberle Koile

extending our evaluator: lazy evaluation

Key ideas:

- procedure args are not evaluated until needed
- represent delayed args as objects
- lazy eval can be added easily
- add new syntax

example a: applicative order

```
(define (foo x)
        (display 'foo)
        (+ x x))

(define (bar x)
    (display 'arg)
    (display x)
     x)
```

(foo (bar 2))

What is printed out? (via display and as a final return value)

a. *applicative order*:

(foo (bar 2)) output

printout

example b: normal (lazy) order

```
(define (foo x)
        (display 'foo)
        (+ x x))

(define (bar x)
    (display 'arg)
    (display x)
     x)

(foo (bar 2))
```

What is printed out? (via display and as a final return value)

a b

b. *normal order (foo's parameter x is delayed)*:

(foo (bar 2)) output

printout

example c: normal with memoization

```
(define (foo x)
        (display 'foo)
        (+ x x))

(define (bar x)
    (display 'arg)
    (display x)
     x)

(foo (bar 2))
```

What is printed out? (via display and as a final return value)

c. *normal order with memoization (foo's parameter is delayed and stored)*

(foo (bar 2)) output

printout

problem 1a: applicative order

1.
```
(define y  5)
(define (foo x)
  (display 'foo)
  (+ x x))
```

```
(define (baz x)
   (display 'arg)
   (set!  y   (+ y  x))
   (display y)
   y)
```

(foo (baz 2))

What is printed out? (via display and as a final return value)

a. *applicative order*

printout

problem 1b: normal (lazy) order

1.
```
(define y 5)
(define (foo x)
  (display 'foo)
  (+ x x))
```

```
(define (baz x)
   (display 'arg)
   (set!  y   (+ y  x))
   (display y)
   y)
```

(foo (baz 2))

What is printed out? (via display and as a final return value)

b. *normal order (foo's parameter x)*

printout

problem 1c: normal order with memoization

1.
```
(define y 5)
(define (foo x)
  (display 'foo)
  (+ x x))
```

```
(define (baz x)
   (display 'arg)
   (set!  y   (+ y  x))
   (display y)
   y)
```

(foo (baz 2))

What is printed out? (via display and as a final return value)

c. *normal order with memoization (foo's parameter x)*

printout

problem 2a: applicative order

```
2.  (define (initialized-list f  n)
      (define (helper  n  lst)
        (if (=  n  0)  lst
            (helper  (-  n  1)  (cons  (f  n)  lst))))
      (helper  n  '()))

    ;  example output:
    (initialized-list  (lambda(x) (*  x  x))  5)
    ;  value  (1  4  9  16  25)
```

```
(define (accum)
  (let  ((count  0))
    (lambda (x)
      (set!  count  (+  x  count))
      count)))
```

What is the value of the statement (initialized-list (accum) 5)

a. *applicative order*

printout

problem 2b: normal (lazy) order

2.
```
(define (initialized-list f n)
   (define (helper  n  lst)
      (if (=  n  0)  lst
         (helper  (-  n  1)  (cons (f  n)  lst))))
   (helper  n  '()))

;  example output:
(initialized-list  (lambda(x) (*  x  x))  5)
;  value  (1  4  9  16  25)
```

```
(define (accum)
   (let  ((count  0))
      (lambda (x)
         (set!  count  (+  x  count))
         count)))
```

What is the value of the statement (initialized-list (accum) 5)

b. *normal order (initialized-list's parameter f)*

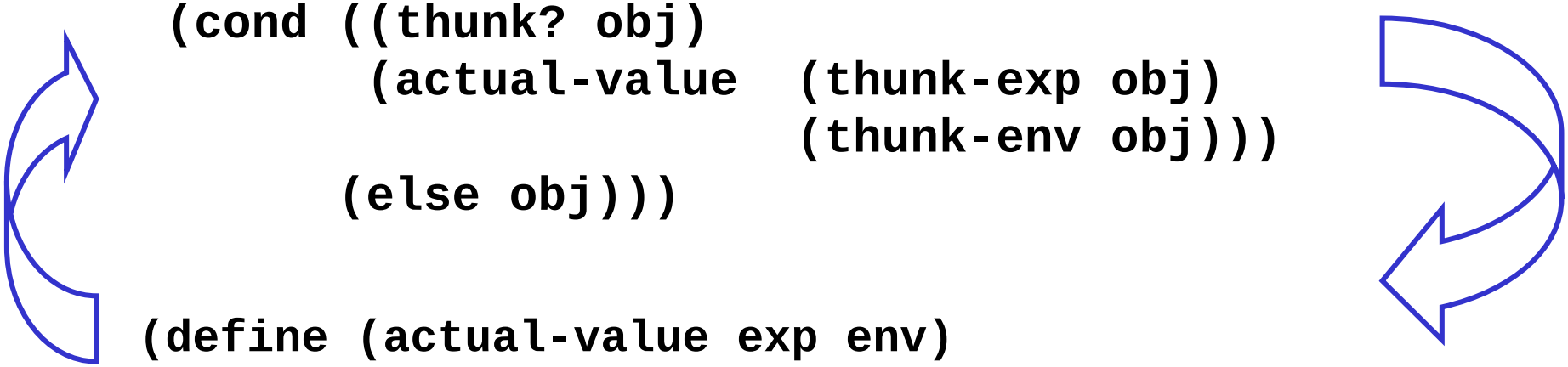
printout

representing delayed objects: thunks

thunks: delay-it, force-it (without memoization)

```
(define (delay-it exp env) (list 'thunk exp env))
(define (thunk? obj) (tagged-list? obj 'thunk))
(define (thunk-exp thunk) (cadr thunk))
(define (thunk-env thunk) (caddr thunk))
```

```
(define (force-it obj)
  (cond ((thunk? obj)
         (actual-value  (thunk-exp obj)
                        (thunk-env obj)))
        (else obj)))
```



```
(define (actual-value exp env)
  (force-it (l-eval exp env)))
```

thunks: memoizing implementation

```
(define (evaluated-thunk? obj)
  (tagged-list? obj 'evaluated-thunk))
(define (thunk-value evaluated-thunk)
  (cadr evaluated-thunk))

(define (force-it obj)
  (cond ((thunk? obj)
         (let ((result (actual-value (thunk-exp obj)
                                     (thunk-env obj))))
           (set-car! obj 'evaluated-thunk)
           (set-car! (cdr obj) result)
           (set-cdr! (cdr obj) '())
           result))
        ((evaluated-thunk? obj)  (thunk-value obj))
        (else obj)))
```

controlling argument evaluation: new syntax