Class Announcements

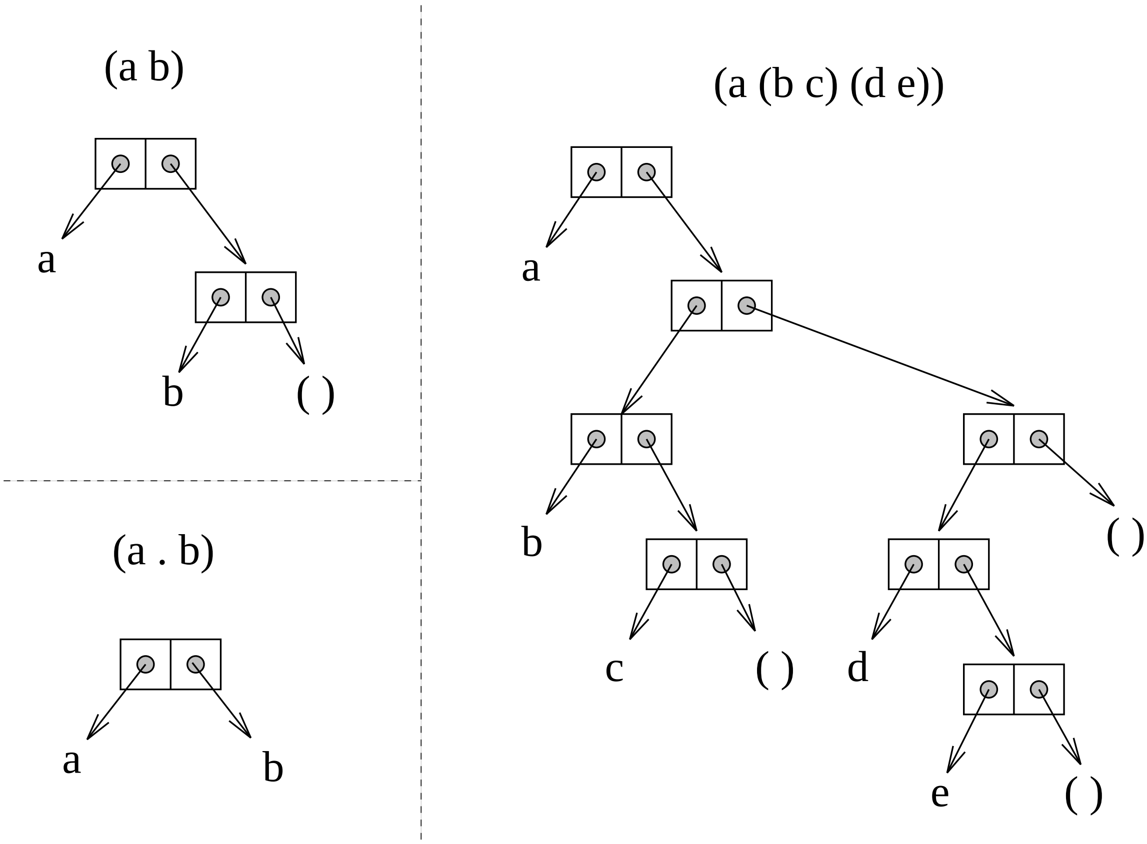
- Fourth homework: Deadline extension - Now Wednesday, March 29. Parameter passing styles will be discussed in recitation
- First project: Deadline extension - Now Monday, March 27.

  REMINDER: You have to check for memory leaks and unitialized variables using `valgrind`.
- Midterms
  - First midterm. If you want to request a regrade, you must do so by Wednesday, April 29.
  - Second midterm date sometime early April.
  - Final (third midterm) exam on Thursday, May 4, noon - 3:00pm timeslot. Location: most likely this room.

    Any CONFLICTS with other classes?
- Functional programming resources: Online book on Scheme; we will use `racket` and `drracket` which you can install on your laptop or machine. Both interpreters are available on our ilab cluster.

Lists in Scheme

The building blocks for lists are pairs or cons-cells. Lists use the empty list ( ) as an "end-of-list" marker.



Note: (a.b) is not a list!

Special (Primitive) Functions

- `eq?`: identity on names (atoms)
- `null?`: is list empty?
- `car`: selects first element of list *(contents of address part of register)*
- `cdr`: selects rest of list *(contents of decrement part of register)*
- `(cons element list)`: constructs lists by adding `element` to front of `list`
- `quote` or `'`: produces constants

Other Functions

- `+ - * /` numeric operators, e.g.,
  `(+ 5 3)` = `8`, `(- 5 3)` = `2`
  `(* 5 3)` = `15`, `(/ 5 3)` = `1.6666666`
- `= < >` comparison operators for numbers
- Explicit type determination and test functions:

  ⇒ All return Boolean values: `#f` and `#t`

  - `(number? 5)` evaluates to `#t`
  - `(zero? 0)` evaluates to `#t`
  - `(symbol? 'sam)` evaluates to `#t`
  - `(list? '(a b))` evaluates to `#t`
  - `(null? '())` evaluates to `#t`

Note: SCHEME is a strongly typed language.

Other Functions

- `(number? 'sam)` evaluates to `#f`
- `(null? '(a))` evaluates to `#f`
- `(zero? (- 3 3))` evaluates to `#t`
- `(zero? '(- 3 3))` $\Rightarrow$ type error
- `(list? (+ 3 4))` evaluates to `#f`
- `(list? '(+ 3 4))` evaluates to `#t`

READ-EVAL-PRINT Loop

The Scheme interpreters on the ilab machines are called mzscheme, racket, and drracket. "drracket" is an interactive environment, the others are command-line based. For example: Type `mzscheme`, and you are in the READ-EVAL-PRINT loop. Use Control D to exit the interpreter.

READ: Read input from user:
a function application

EVAL: Evaluate input:
(f $\texttt{arg}_1$ $\texttt{arg}_2$ ...$\texttt{arg}_n$)

1. evaluate `f` to obtain a function
2. evaluate each $\texttt{arg}_i$ to obtain a value
3. apply function to argument values

PRINT: Print resulting value:
the result of the function application

You can write your Scheme program in file <name>.ss and then read it into the Scheme interpreter by saying at the interpreter prompt: `(load "<name>.ss")`

READ-EVAL-PRINT Loop Example

```
> (cons 'a (cons 'b '(c d)))
(a b c d)
```

1. Read the function application
   `(cons 'a (cons 'b '(c d)))`
2. Evaluate `cons` to obtain a function
3. Evaluate `'a` to obtain `a` itself
4. Evaluate `(cons 'b '(c d))`:
   (a) Evaluate `cons` to obtain a function
   (b) Evaluate `'b` to obtain `b` itself
   (c) Evaluate `'(c d)` to obtain `(c d)` itself
   (d) Apply the `cons` function to `b` and `(c d)` to obtain `(b c d)`
5. Apply the `cons` function to `a` and `(b c d)` to obtain `(a b c d)`
6. Print the result of the application:
   `(a b c d)`

Quotes Inhibit Evaluation

```
;;Same as before:
> (cons 'a (cons 'b '(c d)))
(a b c d)

;;Now quote the second argument:
> (cons 'a '(cons 'b '(c d)))
(a cons (quote b) (quote (c d)))

;;Instead, un-quote the first argument:
> (cons a (cons 'b '(c d)))
ERROR: unbound variable:  a
```

Defining Global Variables

The define constructs extends the current interpreter environment by the new defined (name, value) association.

```
> (define foo '(a b c))
#<unspecified>

> (define bar '(d e f))
#<unspecified>

> (append foo bar)
(a b c d e f)

> (cons foo bar)
((a b c) d e f)

> (cons 'foo bar)
(foo d e f)
```

Recursive Scheme Functions: count-elem

```
(count-elem 'a '(a b a c a ⇒ 3
(count-elem 'a '(a b (a c) ((a)) ⇒ 1
(count-elem* 'a '(a b (a c) ((a)) ⇒ 3
```

```
(define count-elem
  (lambda (x l)
```

```
(define count-elem*
  (lambda (x l)
```

```
)
```

Recursive Scheme Functions: Append

```
(append '(1 2) '(3 4 5) ⇒ (1 2 3 4 5)
(append '(1 2) '(3 (4) 5) ⇒ (1 2 3 (4) 5)
(append '() '(1 4 5)) ⇒ (1 4 5)
(append '(1 4 5) '()) ⇒ (1 4 5)
(append '() '()) ⇒ ()
```

```
(define append
  (lambda (x y)

)
```

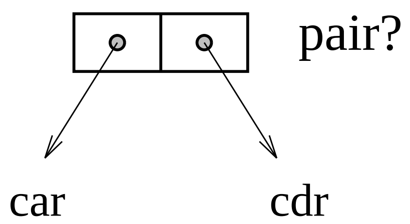
Equality Checking

The `eq?` predicate doesn't work for lists.

Why not?

1. `(cons 'a '())` produces a new list
2. `(cons 'a '())` produces another new list
3. `eq?` checks if its two arguments are *the same*
4. `(eq? (cons 'a '()) (cons 'a '()))` evaluates to `#f`

Lists are stored as pointers to the first element (car) and the rest of the list (cdr). This elementary "data structure", the building block of lists, is called a `pair`.



Symbols are stored uniquely, so `eq?` works on them.

Equality Checking for Lists

For lists, need a comparison function to check for the same **structure** in two lists

```
(define equal?
  (lambda (x y)
    (or (and (atom? x) (atom? y) (eq? x y))
        (and (not (atom? x)) (not (atom? y))
             (equal? (car x) (car y))
             (equal? (cdr x) (cdr y))))))
```

- `(equal? 'a 'a)` evaluates to `#t`
- `(equal? 'a 'b)` evaluates to `#f`
- `(equal? '(a) '(a))` evaluates to `#t`
- `(equal? '((a)) '(a))` evaluates to `#f`

Next Lecture

Practice programming in Scheme

Next time:

- Lambda calculus