Where are We?

Part I: Basic software engineering

- How to represent things
- How to build programs around those representations

Mid-term 1

Part II: Scaling Up

- Abstraction
- Algorithms and state

Mid-term 2

Part III: Another notation, more libraries

- Java

Advanced Scheme

A `<defn>` is one of

```
(define <var> <exp>)
(define (<var> <var> ... <var>) <exp>)
(define-struct <var> (<var> ... <var>))
```

An `<exp>` is one of

```
<var>
<con>
<prim>
(<exp> <exp> ... <exp>)
(cond [<exp> <exp>] ... [<exp> <exp>])
(cond [<exp> <exp>] ... [else <exp>])
(and <exp> ... <exp>)
(or <exp> ... <exp>)
(local [<defn> ...] <exp>)
(lambda (<var> ... <var>) <exp>)
(set! <var> <exp>)
(begin <exp> ... <exp>)
```

Mini Scheme

A `<defn>` is one of

```
(define <var> <exp>)
(define <var> (lambda (<var>) <exp>))
```

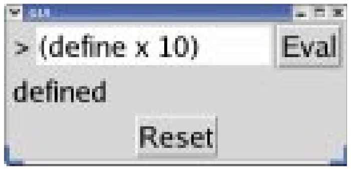
An `<assign>` is

```
(set! <var> <exp>)
```

An `<exp>` is one of

```
<var>
<num>
(+ <exp> <exp>)
(- <exp> <exp>)
(* <exp> <exp>)
(<var> <exp>)
```

HW 10 and 11: Implementing DrMiniScheme



```
> (define x 10)
defined
```

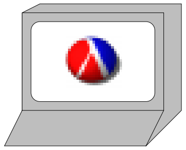
Key design problems for DrMiniScheme:

- Representing definitions and expressions
- Executing definitions and expressions
- Controlling the GUI

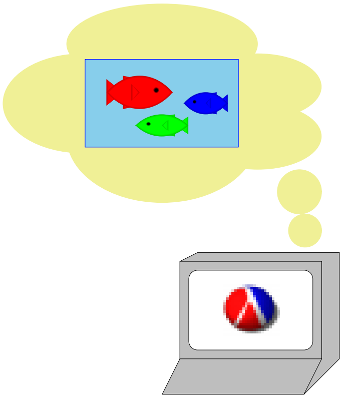
Outline

- **Representing definitions and expressions**
- **Converting strings to representations**
- **Evaluating Expressions**

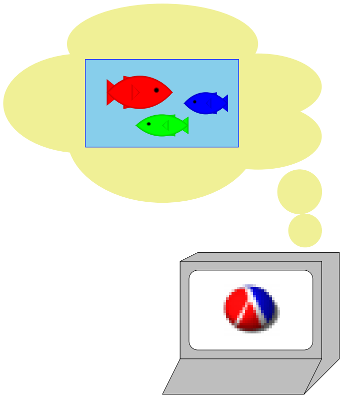
Implementing Aquariums in Advanced Scheme



Implementing Aquariums in Advanced Scheme

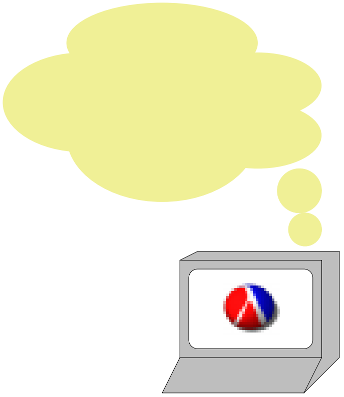


Implementing Aquariums in Advanced Scheme

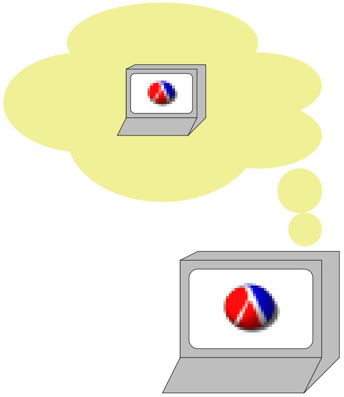


Represent fish, as opposed to stuffing *real* fish into DrScheme

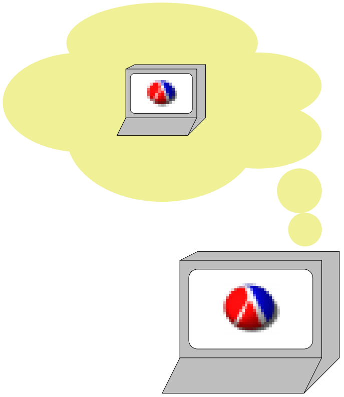
Implementing Mini Scheme in Advanced Scheme



Implementing Mini Scheme in Advanced Scheme



Implementing Mini Scheme in Advanced Scheme



Represent Mini Scheme expressions, as opposed to typing *real* expressions into DrScheme

Representing Mini Scheme Expressions

```
An <exp> is one of
    <var>
    <num>
   (+ <exp> <exp>)
   (- <exp> <exp>)
   (* <exp> <exp>)
   (<var> <exp>)
```

We can’t simply write

```
(+ 1 2)
```

to represent a Mini Scheme addition expression

Representing Mini Scheme Expressions

An `<exp>` is one of

```
<var>
<num>
(+ <exp> <exp>)
(- <exp> <exp>)
(* <exp> <exp>)
(<var> <exp>)
```

We can write

```
’(+ 1 2)
```

which is almost as convenient!

Representing Mini Scheme Expressions

An `<exp>` is one of

```
<var>
<num>
(+ <exp> <exp>)
(- <exp> <exp>)
(* <exp> <exp>)
(<var> <exp>)
```

To represent the `<var>` `x`:

```
’x
```

Representing Mini Scheme Expressions

An `<exp>` is one of

```
<var>
<num>
(+ <exp> <exp>)
(- <exp> <exp>)
(* <exp> <exp>)
(<var> <exp>)
```

To represent the `<num>` `5`:

```
’5
```

which is actually just `5`

Representing Mini Scheme Expressions

An `<exp>` is one of

```
<var>
<num>
(+ <exp> <exp>)
(- <exp> <exp>)
(* <exp> <exp>)
(<var> <exp>)
```

To represent the application `(f (+ 1 2))`

```
’(f (+ 1 2))
```

which is the same as

```
(list ’f (list ’+ 1 2))
```

Representing Mini Scheme Expressions

Data definition:

```
; A expr-snl is either
;   - sym
;   - num
;   - (list ’+ expr-snl expr-snl)
;   - (list ’- expr-snl expr-snl)
;   - (list ’* expr-snl expr-snl)
;   - (list sym expr-snl)
```

Representing Mini Scheme Expressions

A better data definition in the long run:

```
; A expr-snl is either
;   - sym
;   - num
;   - add-expr-snl
;   ...
;
; An add-expr-snl is
;  (list ’+ expr-snl expr-snl)
;
; ...
```

Representing Definitions and Assignments

```
; A defn-snl is either
;   - (list ’define sym expr-snl)
;   - (list ’define sym
;           (list ’lambda (list sym)
;                 expr-snl))
;
; An assign-snl is
;  (list ’set! sym expr-snl)
```

HW 10

HW 10 simplification: only define/assign to numbers, and only evaluate variable names

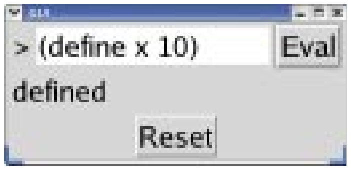
```
; A defn-snl is
;  (list ’define sym num)
;
; An assign-snl is
;  (list ’set! sym num)
;
; An expr-snl is
;  sym
```

Outline

- **Representing definitions and expressions**
- **Converting strings to representations**
- **Evaluating Expressions**

Converting a String to a Mini Scheme Expression

In the GUI, the defininition/assignment/expression is available only as a string:



> (define x 10)

defined

The `read-from-string` teachpack function converts a string by putting a quote in front of it

```
(read-from-string "1") → 1
(read-from-string "(+ 1 2)") → '(+ 1 2)
(read-from-string "(define x 7)")
  → '(define x 7)
```

The snl Datatype

```
; read-from-string : string -> snl

; An snl is either
;   - sym
;   - num
;   - list-of-snl
```

Example `snl`s:

```
'x
1
'(1 1 1 x 1)
```

Not every `snl` is a `defn-snl`, `assign-snl`, or `expr-snl`

Checking for Definitions

```
; is-defn? : snl -> bool
(define (is-defn? s)
  (and (list? s)
       (= 3 (length s))
       (symbol? (first s))
       (symbol=? 'define (first s))
       (symbol? (second s))
       (number? (third s))))
```

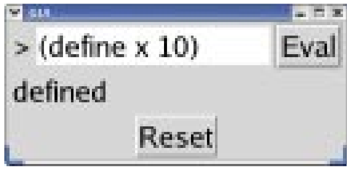
Checking for Expressions (HW 11)

```
; is-expr? : snl -> bool
(define (is-expr? s)
  (or (number? s)
      (symbol? s)
      (is-plus? s)
      ...))

; is-plus? : snl -> bool
(define (is-plus? s)
  (and (list? s)
       (= 3 (length s))
       (symbol? (first s))
       (symbol=? '+ (first s))
       (is-expr? (second s))
       (is-expr? (third s))))

...
```

Executing Code



```
> (define x 10)
defined
```

When the **Eval** button is clicked:

- If it's a definition, record it
- If it's an assignment, do it
- If it's an expression, evaluate it

Execution

```
; execute : snl -> string
(define (execute s)
  (cond
    [(is-defn? s) ...]
    [(is-assign? s) ...]
    [(is-expr? s) ...]
    [else "bad input"]))
...
; execute-string : snl -> string
;  Used by the Execute button callback
(define (execute-string str)
  (local [(define snl (read-from-string str))]
    (cond
      [(boolean? snl) "bad input"]
      [else (execute s)])))
```

Outline

- ➢ **Representing definitions and expressions**
- ➢ **Converting strings to representations**
- ➢ **Evaluating Expressions**

Evaluating Mini Scheme (HW 11)

```
(evaluate ’3) "should be" 3
(evaluate ’(+ 1 2)) "should be" 3
(evaluate ’(+ 1 (* 2 5))) "should be" 11
```

Assuming `(define f (lambda (x) (+ x 1)))`:

```
(evaluate ’(f 7))
```

Evaluating Mini Scheme (HW 11)

```
(evaluate ’3) "should be" 3
(evaluate ’(+ 1 2)) "should be" 3
(evaluate ’(+ 1 (* 2 5))) "should be" 11
```

Assuming `(define f (lambda (x) (+ x 1)))`:

```
(evaluate ’(f 7))
"should be" 8
```

involves substituting `7` into `(+ x 1)`

Evaluating Mini Scheme

```
; evaluate : expr-snl -> value
(define (evaluate s)
  (cond
   [(number? s) ...]
   [(symbol? s) ...]
   [(is-plus? s) ... (evaluate-plus s) ...]
   [(is-minus? s) ... (evaluate-minus s) ...]
   [(is-times? s) ... (evaluate-times s) ...]
   [(is-app? s) ... (evaluate-app s) ...]))
```

Evaluating Mini Scheme

```
; ...
; A plus-expr-snl is
;  (list ’+ expr-snl expr-snl)
; ...

; evaluate-plus : plus-expr-snl -> value
(define (evaluate-plus s)
  ... (evaluate (second s))
  ... (evaluate (third s))
  ...)
```

Evaluating Mini Scheme

```
; evaluate-app : plus-expr-snl -> value
(define (evaluate-app s)
  ... (first s)
  ... (evaluate (second s))
  ...)
```

Assuming the first is defined as a function, the next step is to substitute...

Substitution

Assuming `(define f (lambda (x) (+ x 1)))`:

```
(evaluate-app ’(f (- 20 5)))
  → → (substitute ’x 15 ’(+ 1 x))
```

```
(substitute ’x 15 ’(+ 1 x))
"should be" ’(+ 1 15)
```

Summary

HW 10

- Just definitions, assignments, variable lookup

HW 11

- Expression evaluation
- Optional exercises: errors, conditionals