LAB 11

Scheme

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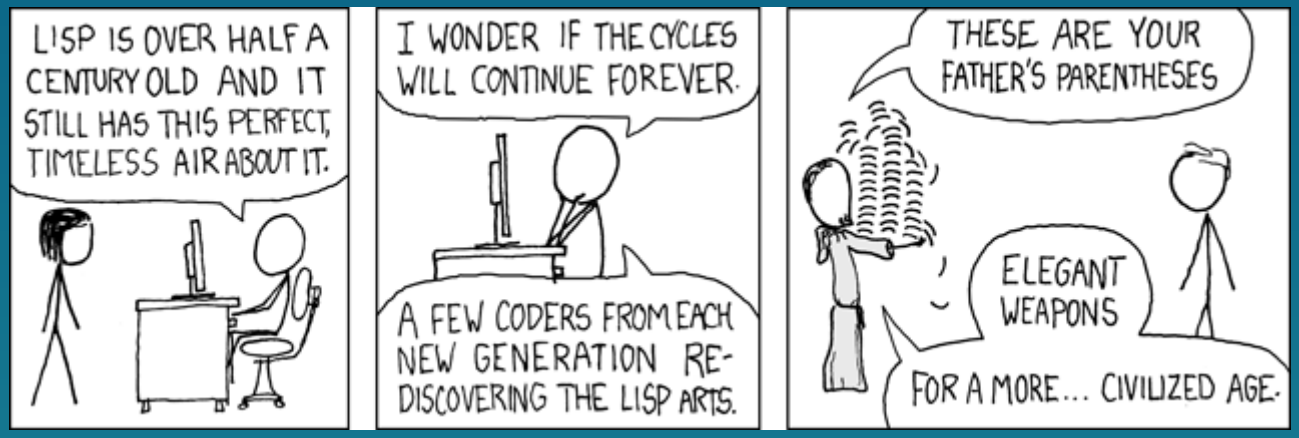
LOGISTICS 

- Congrats on finishing the midterm!
- Welcome to the world of `(scheme)` 
- Lab 11 due tomorrow 4/12
- Homework 08 due Thu 4/13

SCHEME 

SCHEME - INTRO

- A dialect of Lisp (a very old language)
- Uses prefix notations
  - `(func op1 op2)`
  - (many) nested parenthesis as a result



- Features tail-call optimizations - will be covered later
- EVERYTHING IN SCHEME EVALUATES TO A VALUE
  - In contrast, statements in python do not evaluate to anything

SCHEME - LOGISTICS

For assignment with Scheme questions, in the assignment directory:

- start a Scheme interpreter - `python3 scheme`
- run a program interactively - `python3 scheme -i <file.scm>`
- exit the interpreter - `(exit)`
- start the editor - `python3 editor`
  - This is how you can edit the `.scm` file for an assignment
  - save your work (locally) - `Ctrl/Cmd + c`
  - quit the editor - `Ctrl + c`
  - test without quitting the editor - run the ok commands in a separate terminal window
- Scheme Built-In Procedure Reference
- Scheme Specification

PS: You can also edit the `.scm` file in your own editor, but our version has visualizations that makes parenthesis matching much easier!

SCHEME - PRIMITIVE EXPRESSIONS

- Primitive Expressions:
  - self-evaluating
  - Includes numbers, booleans, symbols

```
scm> 6
6
scm> 10.0
10.0
```

SCHEME - PRIMITIVE EXPRESSIONS

- Booleans
  - `#t` in Scheme ↔ `True` in Python
  - `#f` in Scheme ↔ `False` in Python
  - `#f` is THE ONLY FALSY VALUE in Scheme! (0 is truthy!)

```
scm> #t
#t
scm> #f
#f
```

SCHEME - PRIMITIVE EXPRESSIONS

- Symbols
  - a type of value in scheme
  - act like variable names in Python (but not exactly the same)
  - a symbol can evaluate to a value; an expression can also evaluate to a symbol

```
scm> quotient
#[quotient] ; representation of built-in procedures
scm> 'quotient ; Scheme uses single quotation mark
quotient ; the string above evaluates to a symbol
scm> 'hello-world!
hello-world! ; also a symbol value
```

`;` in Scheme denotes comment - just like `#` in Python

SCHEME - CALL EXPRESSIONS

Anatomy: `(func op1 op2 ...)`

- Operator is WITHIN the parenthesis, and comes first
- Operator/operands are separated by whitespace, NOT comma
- Same evaluation rule as in Python:
    1. Evaluate the operator, which should evaluate to a procedure*
    2. Evaluate the operands from left to right
    3. Apply the procedure to the operands

* In Scheme, functions are called procedures

SCHEME - BUILT-IN PROCEDURES

Scheme	Python
`(/ a b)`	`a / b`
`(quotient a b)`	`a // b`
`(modulo a b)`	`a % b`
`(= a b)`	`a == b`
`(not (= a b))`	`a != b`

SCHEME - CALL EXPRESSIONS

```
scm> (+ 1 (* 2 3) (- 5 4)) ; 1 + (2 * 3) + (5 - 4)
8
scm> (- (/ 10 4) 1) ; (10 / 4) - 1
1.5
scm> (modulo 10 4) ; modulo -> %
2
scm> (even? (quotient 45 2)) ; quotient -> //
#f
scm> (not (= 1 2)) ; operands to = must be numbers
#t
```

Exercise: translate `6 * 3 - 2 >= 0` to Scheme

SCHEME - QUOTES

- use a one single quotation mark - `'<expression>`
  - only applies to the expression right after
- Equivalent form: `(quote <expression>)`
- Evaluate to the `<expression>` exactly as it is

```
scm> 'hello-world  ; evaluates to a symbol value
hello-world
scm> '(+ 1 2)
(+ 1 2)
```

SCHEME - SPECIAL FORMS

- Do not follow the rules for call expressions (e.g., short-circuiting)
- Scheme Specification - complete list of special forms
- Includes `and`, `or`, `if`, `cond`, etc.

```
scm> (and 0 1 2 3) ; 0 in Scheme is truthy!
3
scm> (or 0 1 2 3)
0
scm> (and (> 1 6) (/ 1 0)) ; short-circuiting applies
#f
scm> (or (< 1 6) (/ 1 0))
#t
```

SCHEME - CONTROL STRUCTURES

`(if <predicate> <if-true> [if-false])`*

- Evaluation rules
    1. Evaluate `<predicate>`
    2. If it evaluates to a truthy value, evaluate and return `<if-true>`. Otherwise, evaluate and return `[if-false]`
    3. `[if-false]` is optional. If not provided and `<predicate>` is falsy, returns `undefined` - Scheme's version of `None` (not displayed in the interpreter unless printed)
- Only one of `<if-true>` and `[if-false]` is evaluated
    - The entire special form evaluates to either `<if-true>` or `[if-false]`
- No `elif` - if more than 2 branches, use nested `if`'s or `cond`

* In our Scheme Specification, `<>` is used to denote required components while `[]` is used to denote optional components

SCHEME - CONTROL STRUCTURES

Scheme	Python

`(if (> x 3)`
`  1`
`  2)`
	`if x > 3:`
	`  return 1`
	`else:`
	`  return 2`

`(if (< x 0)`
`  'negative`
`  (if (= x 0)`
`  'zero`
`  'positive`
`  )`
`)`
	`if x < 0:`
	`  return 'negative'`
	`else:`
	`  if x == 0:`
	`  return 'zero'`
	`  else:`
	`  return 'positive'`

Note: Indentation / line break does NOT matter in Scheme

SCHEME - CONTROL STRUCTURES

Scheme `if`	Python `if`
A special form expression that evaluates to a value	Some statement that directs the flow of the program
Expects just a single expression for each of the true result and the false result	Each suite can contain multiple lines of code
No `elif`	Has `elif`

SCHEME - CONTROL STRUCTURES

```
(cond
    (<p1> <e1>)
    ...
    (<pn> <en>)
    [(else <else-expression>)]) ; else is optional
```

- Similar to a multi-clause if/elif/else conditional
- Takes in an arbitrary number of arguments - clauses
  - Clause: `(<p> <e>)`
- Evaluation rules:
  1. Evaluate the predicates `<p1>`, `<p2>`, ..., `<pn>` in order until a truth-y value
  2. For the first truthy predicate, evaluate and return the corresponding expression in the clause
  3. If none are truth-y and there is an `else` clause, evaluate and return `<else-expression>`; otherwise return `undefined`

SCHEME - CONTROL STRUCTURES

```
(cond
    (<p1> <e1>)
    ...
    (<pn> <en>)
    [(else <else-expression>)]) ; else is optional
```

- special form - does not evaluate every operands
  - short circuits upon reaching the first truthy predicate
- Only one clause has its `<e>` evaluated (and returned)
  - The whole `cond` special form evaluates to the value of this `<e>`
- Order of clauses matters
  - only move to the next clause if all previous predicates are falsy

SCHEME - CONTROL STRUCTURES

Scheme	Python

`(cond`
`  ((> x 3) 1)`
`  (else 2)`
`)`
	`if x < 3:`
	`  return 1`
	`else:`
	`  return 2`

`(cond`
`  ((> x 0) 'positive)`
`  ((< x 0) 'negative)`
`  (else 'zero)`
`)`
	`if x > 0:`
	`  return 'positive'`
	`elif x < 0:`
	`  return 'negative'`
	`else:`
	`  return 'zero'`

Note: Indentation / line break does NOT matter in Scheme

SCHEME - DEFINE VARIABLES

`(define <name> <expression>)`

- Evaluation rules
  1. Evaluate the `<expression>`
  2. Bind its value to the `<name>` in the current frame
  3. Return `<name>` as a symbol
- Evaluates to `<name>` (a symbol value)

```
scm> (define x (+ 6 1))
x
scm> x
7
scm> (+ x 2)
9
```

SCHEME - DEFINE FUNCTIONS

```
(define (<func-name> <param1> <param2> ... ) <body>)
```

- Evaluation rules
  1. Create a lambda procedure with the given parameters and `<body>`
  2. Bind its procedure to the `<func-name>` in the current frame
  3. Return `<func-name>` as a symbol
- Evaluates to `<name>` (a symbol value)
- `<body>` can have multiple expressions
  - all expressions are evaluated from left to right, and the value of the last expression is returned
- Special form - function body not evaluated until the function is called

SCHEME - DEFINE FUNCTIONS

```
(define (<func-name> <param1> <param2> ... ) <body>)
```

```
scm> (define (foo x y) (+ x y))
foo
scm> (foo 2 3)
5
```

SCHEME - LAMBDA FUNCTIONS

```
(lambda (<param1> <param2> ... ) <body>)
```

- Create and return a procedure , without altering the current environment unless we bind it to a variable.
- All Scheme procedures are lambda procedures!
- `<body>` can have multiple expressions
  - all expressions are evaluated from left to right, and the value of the last expression is returned

```
scm> (define foo (lambda (x y) (+ x y)))
foo
scm> (define (foo x y) (+ x y)) ; these two are equivalent
foo
scm> (foo 2 3)
5
scm> (lambda (x y) (+ x y))
(lambda (x y) (+ x y))
```

NOW IT'S YOUR TIME 

- Get started on the lab and raise your hand whenever you need help!
- Get to know your neighbors and collaborate if you'd like!
- Slides: go.cs61a.org/mingxiao-index
- Leave any anonymous feedback here: go.cs61a.org/mingxiao-anon

AND REMEMBER TO GET CHECKED OFF! 

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go.cs61a.org/mingxiao-att

The secret phrase is ...
(NOT 3 dots! I'll announce it 🙉)