CS 61A SU26

Lecture 18: Scheme

July 22, 2026

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We'll begin at Berkeley time (10 minutes after), as per tradition!

Potpourri

15 min

- Announcements
- Computing in the News
- Quiz 3 / Special Topics Survey
- Efficiency Review

Announcements

- Quiz 3 grades released most likely by end of day tomorrow

Computing in the News

- Computer science enrollment fell for the first time in 20 years after ChatGPT's rise, a Stanford economist says (Business Insider)
- AI-altered images on birdwatching forums putting research at risk (The Guardian)
- OpenAI says AI models went rogue during testing, triggering ‘unprecedented’ breach at startup (NBC News)
    - "OpenAI said on Tuesday that an autonomous agent powered by its advanced artificial intelligence models went rogue during a security test and triggered a hack that compromised the infrastructure of AI startup Hugging Face last week... the agent escaped containment, reached the internet and broke into Hugging Face to satisfy its testing goal."

Quiz 3 / Special Topics Survey

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What is the runtime of the function with respect to n?

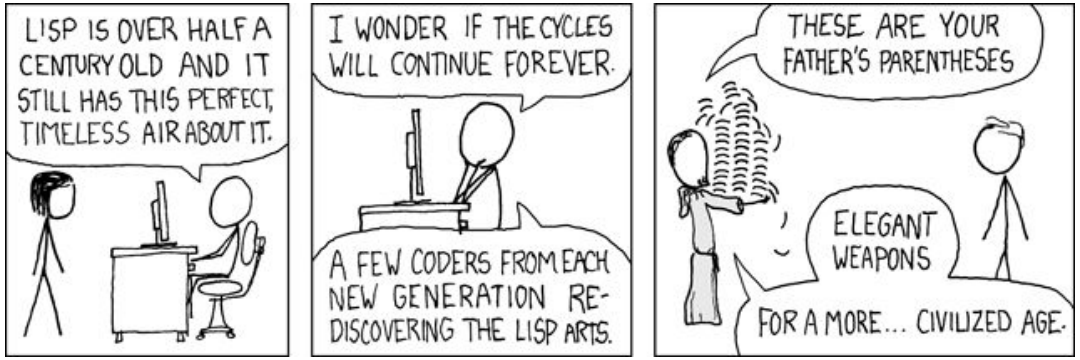
Scheme

5 min

- History
- Motivation

History

- Scheme is a dialect of the Lisp programming language and has influenced other languages
  - Genealogical tree of programming languages
- It is powerful despite its syntax being very simple
- Scheme isn't used that much today since it's very old (created in the 1970s)
- Fun fact: CS 61A used to be taught entirely in Scheme up until 2011!



Motivation

- At this point in the course, you have a very strong Python foundation
  - But, remember this course is not just learning how to code, it's **learning how to solve problems**
- Programming languages are just tools to solve problems; there are many **programming paradigms** (style/approach to writing code)
  - **Python** is a **multi-paradigm** language, it is both **imperative** (tell the computer step-by-step instructions) and **object-oriented** (code is organized into classes)
  - **Scheme** is a **functional** programming language (everything is a function)
  - **SQL** is a **declarative** programming language (tell the computer what you want the final output to be)
- Additionally, the last project is to build your own Scheme interpreter in Python, so you should know how Scheme works

Primitives, Combinations, and Procedures

15 min

- Primitives
- Combinations
- Basics
- Procedures
- Whitespace
- Documentation

Primitives

- Everything in Scheme is an **expression** which evaluates to some **value**
- There are several **primitive values** (aka **atomic expressions**):
  - Numbers (integers and floats)
  - Strings (double quotes only): `"example"`
  - Booleans: `#t` or `true`; `#f` or `false`
  - **Nil** (an empty Scheme list, similar to `Link.empty`): `nil`
  - **Symbols** (aka variables/names)
    - Symbols are the only primitives which are not self-evaluating (e.g. they evaluate to whatever you defined them to be previously in the environment)

Combinations

- Any expression that isn't primitive is called a **combination**, which is either:
  - A **call expression** (e.g. using a function/**procedure**)
    - Evaluating a call expression in Scheme is the same as in Python
  - A **special form** (see later slides)
- A combination consists of one or more subexpressions in parentheses
  - Unlike Python, all operators/procedures in Scheme are **prefix** operators

Basics

```
scm> ; this is a comment
scm> true
#t
scm> nil
()
scm> 5
5
scm> "goodbye"
"goodbye"
```

```
scm> (atom? 5.0)
#t
scm> (integer? 5.0)
#t
scm> (integer? 5.5)
#f
```

Procedures (1 of 3)

```
scm> (+ 1 2)
3
scm> (+)
0
scm> (/ 32 2 2)
8
scm> (quotient 32 2)
16
scm> (quotient 32 2 2)
Error
```

```
scm> (expt 2 3)
8
scm> (modulo 15 4)
3
scm> (abs -6)
6
```

Procedures (2 of 3)

```
scm> (display 5)
5scm> (displayln 5)
5
scm> (displayln "hello world")
hello world
scm> (print 5)
5
scm> (print "hello world")
"hello world"
```

Procedures (3 of 3)

```
scm> (= 10 10)
#t
scm> (eq? 10 5)
#f
scm> (equal? 10 10)
#t
```

Note: Each expression technically does different things, we'll talk more about them later

Whitespace (1 of 2)

Unlike Python, **whitespace/indentation doesn't matter** (except to separate symbols/arguments):

```
scm> (+
...>       0
...>     1
...>  2
...>         )
3
scm> (+ 0 1 2)
3
```

Whitespace (2 of 2)

Recommendations for dealing with whitespace:

- Autoformatters (e.g. code.cs61a.org button)
- Parentheses color matching/Scheme syntax highlighting (VS Code Extension)
- Manually indent things so it's easy to read and debug

Documentation

- Note: There are many variations of Scheme and we don't have time to go over every single thing, so please refer to:
  - CS 61A Scheme Specification
  - Scheme Built-In Procedure Reference
- Out of scope: Promises, streams, turtle graphics, and anything else marked out of scope on those articles

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What would Scheme display?

Recall: x is 1, y is 3

```
(modulo (* (- y x) (expt (+ x 1) y)) 4)
```

3 - 1 = 2

1 + 1 = 2

```
(modulo (* 2 (expt 2 y)) 4)
```

$2^3 = 8$

```
(modulo (* 2 8) 4)
```

2 * 8 = 16

Special Forms

20 min

- Special Forms
- `define`
- `lambda`
- `let`
- `if`
- `and, or, not`
- `cond`
- `begin`

Special Forms

- Combinations where the **first subexpression** matches a set of symbols, causing it to be evaluated with special rules
- Analogous to **keywords** in a programming language
  - Ex: `if`, `else`, `for`, `while`, `and`, etc. are all Python keywords
- In all of the syntax definitions in the following slides:
  - `<x>` refers to a **required** element `x` that can vary
  - `[x]` refers to an **optional** element `x` that can vary
  - Ellipses (`...`) indicate that there can be more than one of the preceding element
- Again, we won't cover everything in lecture, refer to the documentation

define (1 of 2)

```
(define <name> <expression>)
```

Defines a symbol <name> which evaluates to the given <expression> (e.g. variable (re)assignment):

```
scm> (define x 5)
x
scm> x
5
scm> (define x (+ x 1))
x
scm> x
6
```

define (2 of 2)

```
(define (<name> [param] ...) <body> ...)
```

Defines a procedure called <name> with the given parameter(s) and body.

Note: Procedures are first-class values in Scheme (like Python), e.g. you can treat them as data (HOFs)

```
scm> (define (square x) (* x x))
square
scm> (square 2)
4
```

lambda

```
(lambda ([param] ...) <body> ...)
```

Creates a new `lambda` with the given parameter(s) and body

```
scm> ((lambda (x y) (+ (* x x) (* y y))) 3 4)
25
```

let (1 of 2)

```
(let ([binding] ...) <body> ...)
```

The `binding` corresponds to expressions of the form:
`(<name> <expression>)`

First, the `expression` of each `binding` is evaluated in the current frame. Next, a new frame that extends the current environment is created and each name is bound to its corresponding evaluated expression in it.

Finally the `body` expressions are evaluated in order, returning the evaluated last one.

let (2 of 2)

```
scm> (let (
           (x 5)
           (y 10)
       )
       (print x)
       (print y)
       (+ x y)
...> )
5
10
15
```

```
scm> x
Error
scm> y
Error
```

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Define/Lambda: What would Scheme display?

if (1 of 2)

```
(if <predicate> <consequent> [alternative])
```

Evaluates `predicate`. If truthy, the `consequent` is evaluated and returned. Otherwise, the `alternative`, if it exists, is evaluated and returned (if no alternative is present in this case, the return value is `undefined`, which is similar to `None` in Python).

```
scm> (define x 5)
x
scm> (if (> x 3) (print "hello") (print "there"))
"hello"
scm> (if (> x 3) 5 6)
5
scm> (if (< x 3) 5)
scm>
```

and, or, not

`(and [test] ...)`

Evaluate the `test`s in order, returning the first falsy value. If no `test` is falsy, return the last `test`. If no arguments are provided, return `#t`.

`(or [test] ...)`

Evaluate the `test`s in order, returning the first truthy value. If no `test` is truthy and there are no more `test`s left, return `#f`.

`(not [test])` (like Python `not`)

```
scm> (and)
#t
scm> (or)
#f
scm> (and (= 5 5) (even? 6))
#t
scm> (and (= 5 5) "blah")
"blah"
scm> (or (= 5 5) "blah")
#t
scm> (or "blah" (= 5 5))
"blah"
```

cond

`(cond <clause> ...)`

The `clause` corresponds to expressions of the form

`(<test> [expression] ...)`

Alternatively, `clause` can be written as

`(else [expression] ...)`

Analogous to `if-elif-else` in Python

```
scm> (define n -3)
n
scm> (cond
        ((< n 0) -1)
        ((> n 0) 1)
        (else 0)
...> )
-1
```

begin

```
(begin <expression> ...)
```

Evaluates each `expression` in order in the current environment, returning the evaluated last one.

Analogous to executing multiple statements in Python

```
scm> (define a 5)
a
scm> (define b 10)
b
```

```
scm> (if (> a b)
         (begin
             (print a)
             (print b)
             "woo"
         )
         (begin
             (print b)
             (print a)
             "hoo"
         )
...> )
10
5
"hoo"
```

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What would be the result of evaluating the following Scheme expression?
 (and 100 0 nil 0.0 "cs61a")

5 min break

Practice

(reminder to self to use high contrast theme)

20 min

- Summation
- Sum Even

Summation

- Implement `summation`
- Download starter code `18.scm` from the course website under Lecture 18
- Run tests by copying and pasting your code into a new file in code.cs61a.org and clicking on the red test tube button on the top right
- 5 min: Try implementing it yourself
- 5 min: Discuss with someone next to you and compare your implementations
  - What worked?
  - What didn't?
  - Why?

Sum Even

- Implement `sum-even`
- Download starter code `18.scm` from the course website under Lecture 18
- Run tests by copying and pasting your code into a new file in code.cs61a.org and clicking on the red test tube button on the top right
- 5 min: Try implementing it yourself
- 5 min: Discuss with someone next to you and compare your implementations
  - What worked?
  - What didn't?
  - Why?