2 Scheme Introduction

What's in This Set of Notes ?

2.1 Lisp and Scheme

- Lisp (LISt + Processing)
  - invented late 1950's
  - formalism for reasoning about the use of recursive equations as a model of computation

```
f = a*x + b
x = g(f) + c
```

  - John McCarthy's paper: "Recursive Functions of Symbolic Expressions and Their Computation by Machine"
- Scheme
  - dialect of Lisp
  - invented in 1975 by Guy Steele and Gerald Sussman, MIT
  - IEEE Standard in 1990
- Important feature
  - processes, called procedures, can be manipulated as data

2.2 Expressions

- present interpreter expression, it displays result of its evaluation
- Numbers

```
486  => 486
```

- Variables

```
dog => 2
```

- expression with numbers combined with expression representing primitive procedure form *Compound Expression*

```
(+ 4 1) => 5
(- 4 1) => 3
(* 4 5) => 20
(/ 10 5) => 2
(+ 2.7 10) => 12.7
```

- Expression like these when delimited with parentheses to denote procedure application are called *combinations*

```
(operator operand1 operand2 ..)
```

- prefix notation
- advantages

  many operands possible

  ```
  (+ 21 35 12 7) => 75
  ```

  allows combinations to be nested

  ```
  (+ ( * 3 5) (- 10 6)) => 19
  ```

  no limit

  ```
  ( + ( * 3 ( + ( * 2 4) (+ 3 5))) (+ ( - 10 7) 6))
  ```

  with help from formatting

  ```
  ( + ( * 3
       ( +     ( * 2 4)
             (+ 3 5)))
       (+ ( - 10 7) 6))
  ```

2.3 Naming and Environments

- Name identifies a variable whose value is object
- Name *binds* a variable to a computational object

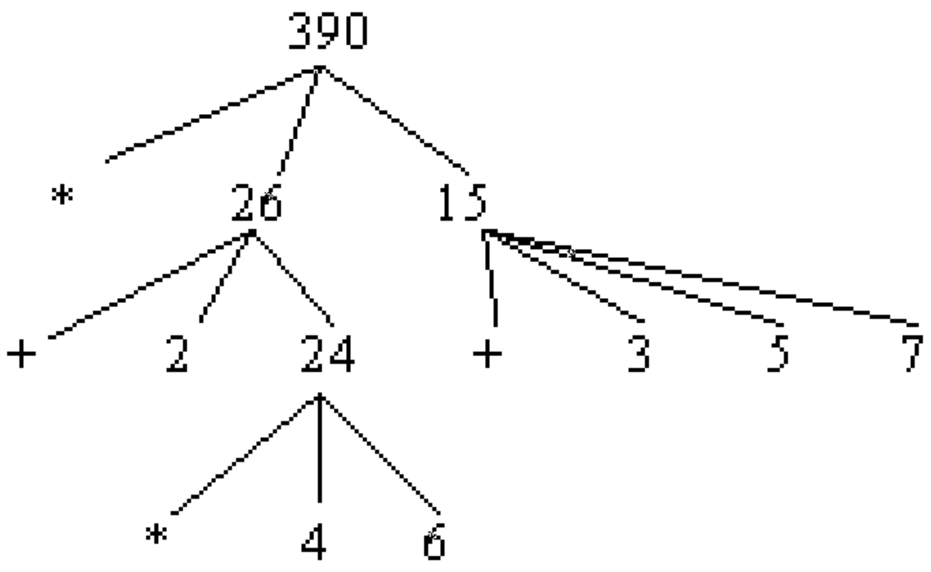
```
(define size 2)          size => 2
(* 5 size) => 10
(define pi 3.14159)
(define radius 10)
(define circumference ( * 2 pi radius))
circumference => 62.8318
```

- Interpreter must maintain *name-object pairs*
- This memory is called the *environment* (global environment)

2.4 Evaluating Combinations

- Evaluation Rule
  1. evaluate subexpressions of combination
  2. apply procedure to resulting arguments
- Note, the approach is recursive

```
(*       ( + 2 ( * 4 6))
        (+ 3 5 7))
```



- Terminals: operators or numbers
- Nodes: combinations
- the values of numerals are the numbers that they name
- the values of built-in operators ar the machine instructions sequences that carry out the corresponding operations
- the values of other names are the objects associated with the names in the environment

- Problem: evaluation rule does not handle definitions

  (define x 3) does not apply define to two arguments, one of which is the symbol x, the other of which is 3)
- Exceptions to general evaluation rules are called *special forms*
  - have own evaluations rules

2.5 Compound Procedures

- What elements in Scheme must appear in any powerful programming language?
  1. Numbers and arithmetic operations are primitive data and procedures
  2. Nesting of combinations provides a means of combining operations
  3. Definitions that associates names with values provides a limited means of abstractions

Procedure Definitions

- Abstraction technique
- Operations given name and referred to as a unit
- General form: (define (<name> <formal parameters>) <body>)

```
(define (square x) (* x x))
(square 21) => 441
(square ( + 2 5)) => 49
```

- suppose we want x squared plus y squared

```
(+ (square x) (square y))
```

- or

```
(define (sum-of-squares x y) (+ (square x) (square y)))
(sum-of-squares 3 4) => 25
```

- What is the answer to the following:

```
(define (f a) (sum-of-squares (+ a 1) (* a 2)))
(f 5) => 136
```

2.6 Substitution Model for Procedure Application

- Think about procedure application
- Determines "meaning" of procedure application
- *Applicative-Order evaluation* (Scheme approach)

1. evaluate operator and operands
2. apply the resulting procedure to resulting arguments

```
(f 5)
(sum-of-squares (+ 5 1) (* 5 2))
(+ (square 6) (square 10))
(+ ( * 6 6 ) (* 10 10))
(+ 36 100)
136
```

- *Normal-Order evaluation* (expand and reduce)

1. substitute operand expressions for parameters until reaching primitive operators,
2. then evaluate

```
(f 5)
(sum-of-squares (+ 5 1) (* 5 2))
(+ (square (+ 5 1)) (square (* 5 2)))
(+ ( * (+ 5 1) (+ 5 1) ) (*  (* 5 2) (* 5 2)))
(+ (* 6 6) ( * 10 10))
(+ 36 100)
136
```

- Which evaluation technique is better?

- both approaches result in the same answer *(generally)*
- applicative-order evaluation is more efficient -> avoid multiple evaluations
- normal-order also has benefits, will see later