SlytherLisp Introduction

Principles of Programming Languages

Colorado School of Mines

`https://lambda.mines.edu`

Cons Cells: Building Blocks of PL

A **cons cell** (short for "construct") is a data structure for which we can build many others from. It consists of two references to other objects.

CAR: Contents of the address register
CDR: Contents of the decrement register

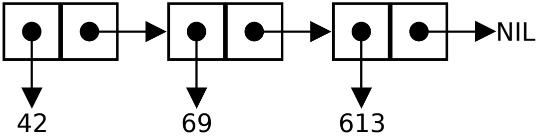
Both can be a reference (e.g., pointer) to anything.

Building Lists using Cons Cells

Suppose we want to represent a list using cons cells. We can take inspiration from linked lists:

- **CAR** will be a reference to the list item.
- **CDR** will be a reference to the next cell.
- The last item in the list will have a CDR with the special value **NIL**.

For example, here is a **cons cell diagram** for the list `(42 69 613)`:



Building Trees using Cons Lists

Represent the following AST using cons cells:

```
(+ (/ 10 2) (* 3 3))
```

What is SlytherLisp?

- SlytherLisp is a programming language.
- You’re going to implement an interpreter for this language.

Basic Syntax

SlytherLisp uses **s-expressions** as its unit of syntax. For example, to write

$$\frac{2^3}{4 \times 5}$$

in SlytherLisp, you would use:

```
(/ (expt 2 3) (* 4 5))
```

Built-in Math Functions

`+`	`expt`	`remainder`
`-`	`sqrt`	`ceil`
`*`	`abs`	`floor`
`/`	`floordiv`	

More Built-in Functions

- `print`, which takes *n* arguments and prints them separated by spaces on the same line (just like Python!):

  ```
  (print "Hello, World!")
  ```

- `input`, which prompts for a line of input and returns the typed string.

  ```
  (input "What is your name? ")  ;; => "Jack"
  ```

Variables

The `define` syntax can be used to define a variable:

```
(define variable-name value)
```

For example:

```
(define name (input "What is your name? "))
(print "Nice to meet you," name)
```

Defining Our Own Functions

Using the `define` syntax, we can also add to the language with our own functions:

```
(define (function-name parameter-name...)
  statement-1
  ...
  statement-n)
```

For example, we could define a function to determine if a number is even or not.

```scheme
(define (is-even? n)
  (not (remainder n 2)))

(is-even? 10)  ;; => #t
(is-even? 11)  ;; => #f
```

Selection: Using if

`if` is a syntax which looks like this:

(if *predicate consequent alternative*)

Here is an example:

```
(define age (make-integer (input "How old are you? ")))

(print (if (<= age 18)
         "Minors not allowed."
         "Welcome"))
```

What's Special About if?

Suppose we want to define our own `if` function, like so:

```
(define (my-if predicate consequent alternative)
  (if predicate consequent alternative))
```

What could go wrong?

Functions vs. Macros

In SlytherLisp, there's two different kinds of things you can put at the beginning of an s-expression to be called:

Functions: *What you are familiar with:* `eval` *is called recursively on the parameters, then the function is called on the results.*

Macros: *Macros don't get the convenience of having their parameters evaluated for them: they have to choose when (and if) this happens. Instead of returning a result, macros return an AST to replace their position.*

What can users make?

- **Functions:** Primitive (built-in) and user crafted
- **Macros:** Primitive only -- user crafted macros can be added to your implementation for extra credit

Both macros and functions are first class, and can be passed around just like normal data. They even both live in the same namespace as variables.

Recursion

Recursion is SlytherLisp's only technique for iteration. For example, to compute the sum of numbers from 1 to 100:

```
(define (sum-to-100)
  (define (sum-iter n a)
    (if (= 0 n)
      a
      (sum-iter (- n 1) (+ n a))))
  (sum-iter 100 0))
```

Some kinds of recursion can be optimized into simple loops. We will learn about this in the coming weeks.

Scoping

- A **scope** refers to the period of which a variable is visible.
- Languages limit the scope of variables to be just within the function to help avoid the risk of collision in two identically named variables. But it raises the question: *what does it mean to be within a function?*
  - In **lexical scoping**[1], the variable is visible when it is within the same function *structure-wise*.
  - In **dynamic scoping**, the variable is visible when it is within the same function *environment-wise*.

[1] Also called "static scoping".

Lexical Scoping

SlytherLisp uses lexical scoping: a variable is in scope when it is within the same function *structure-wise*.

```
(define (reference base)
  (define (get-absolute offset)
    (+ base offset))
  get-absolute)

(define my-reference (reference 10))
(my-reference 5)      ;; => 15
```

Closures

The term **closure** refers to a function and it's definition environment. It's what kept track of the variables where the function was defined in the previous example.

We can use closures to maintain internal state:

```
(define (counter value)
  (define (change-value delta)
    (set! value (+ value delta))    ;; set! will change a variable
                                    ;; rather than define a new
    value)
  change-value)

(define my-counter (counter 5))
(print (my-counter 2))              ;; => 7
(print (my-counter -3))             ;; => 4
```

Brainstorm uses for closures with your learning group.

Closures in JavaScript

```javascript
/* A Lehmer Linear Congruential Generator in JavaScript */
function prng(seed) {
    var x = seed;
    function next() {
        x = (16807 * x) % 2147483647;
        return x;
    }
    return next;
}
```

Dynamic Scoping

In **dynamic scoping**, the calling environment determines the visible variables. Suppose that SlytherLisp used dynamic scoping:

```
(define (func-a x)
  (+ x y))

(define (func-b x)
  (define y 2)
  (func-a x))

(print (func-b 10))      ;; => 12
```

Exercise

Consider this code:

```
(define (func x)
  (define y x)
  (define (f z)
    (+ y z))
  f)

(define adder (func 3))
(define y 2)
(print (adder -2))
```

- What would be printed if the language used Dynamic Scoping?
- What would be printed if the language used Lexical Scoping?

Why would we ever choose dynamic scoping?

- Easy to implement
- First class functions don’t need to carry around definition environment

Scoping in the Wild

- **Static:** C, C++, Pascal, Python
- **Dynamic:** C preprocessor macros, Early Lisps, Emacs Lisp, Bash
- **Allows both:** Common Lisp, Scheme, Perl