L02 Lisp

Lisp

Lisp: a family of programming languages based on s-expressions

- Lisp code can be represented as a list (Code can be represented as **data**)

Why study Lisp?

- Different way of thinking about programming
- Functional programming (lisp has good support)
- Symbolic Computing: manipulating symbolic expressions

Outline

Symbolic computing

- Rewrite Systems
- Implementing expressions
- List manipulation

Lisp programming overview

Implementation details

Symbolic Computing

Rewrite system (A **formal system** or **calculus**): a well defined method for mathematical reasoning employing axioms and rules of inference or transformation.

- Set of rules to transform or rewrite mathematical expressions
- Ex. Given $3x + 1 = 10$, find x. You use a rewrite system to obtain x

Cons Cell

Cons cell is just a node in a singly-linked list

Declaration:

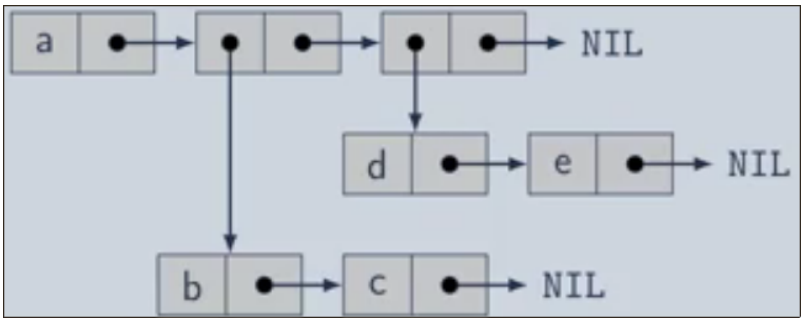
```
struct cons {
    void *first
    struct cons *rest
}
```

Diagram:

- CAR: data in the node
- CDR: points to the rest of the list

Nested Lists

(a (b c) (d e))



Con cells CAR point to a nested list

Abstract Syntax

In Abstract Syntax we have:

- **Function/Operator**
- **Arguments/Operand**

In Abstract Syntax Tree we have:

- **Root**: Function/operator
- **Children**: Arguments/operand

In S-Expression we have:

- **First**: Root, Function/operator
- **Rest**: Children, Arguments/operand

S-Expression can represent AST

S-Expression can represent list

AST can represent list and vice-versa

Evaluation and Quoting

Evaluation: Evaluating (executing) an expression and yielding its return value

- Ex. (fun a b) return value of fun
- Ex. (+ 1 2) → 3

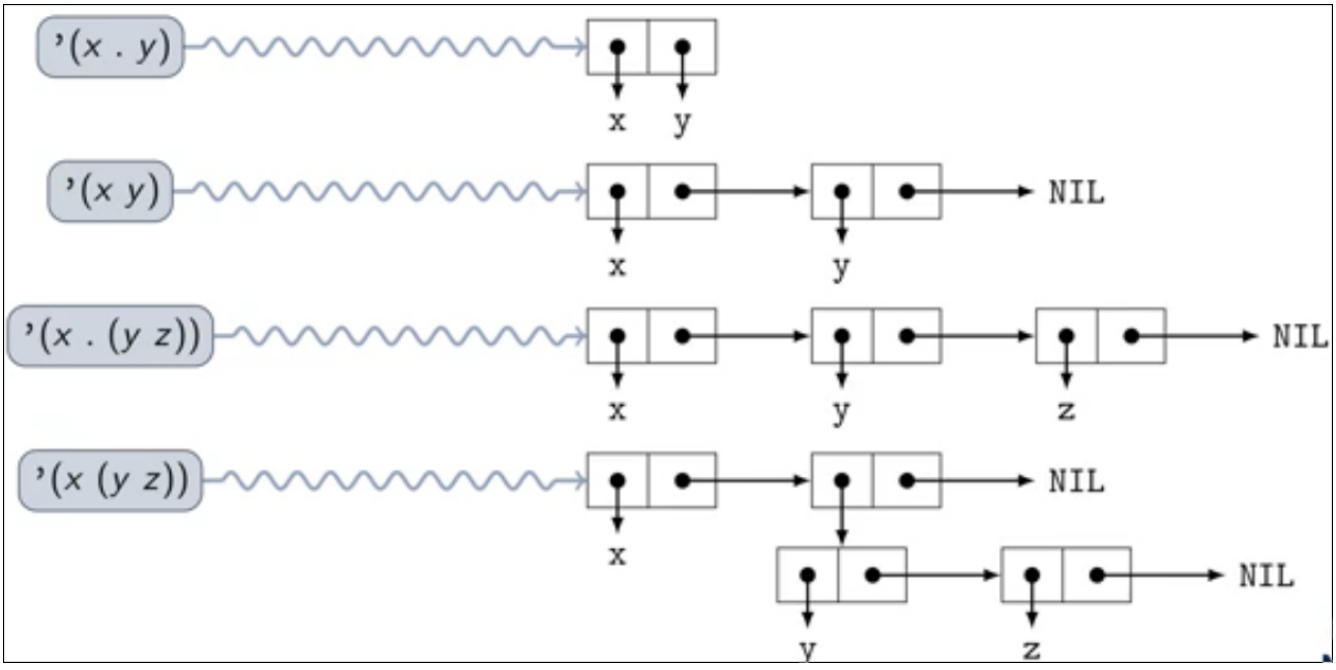
Quoting: Returns the quoted s-expression

- Ex. '(+ 1 2) → (+ 1 2)

List Manipulation

Dotted List Notation

Dotted list notation allows us to define the CAR and CDR of a con cell



CONStruct Function

Construct a new cons cell:

`(cons x y)` → a fresh con cell with x as the CAR (first) and y in the CDR (rest)

If y (CDR) is an existing list, the CDR points to the front of that list

(cons 2 (cons 1 NIL)) = Con cell 2 pointing to con cell 1 to NIL

List Function

List: return a list containing the supplied objects

`(list a0 ... an)` → a list containing objects $a_0, \ldots, a_n$

List Access

Con Cells = [CAR][CDR]

CAR: returns the car of a cons cell

(car cell) → the CAR (first) of cell

CDR: returns the rest of a cons cell

(cdr cell) → the CDR (rest) of cell

List Template Syntax

Backquote (’): Create a template

’(x_0 … x_n) → (list ’x_0 … ’x_n)

Ex. ’(+ a (* b c)) → (+ a (* b c))

Comma (,): Evaluate and insert

’(α … **y** β) → (list α … **evaluated y** β)

Ex. ’(+ a ,(* 2 3)) → (+ a 6)

Comma-At (,@): Evaluate and splice

’(α … ,@**y β) → (**append** α **…** spliced y** β)

Ex. ’(+ a ,@(list (* 2 3) (* 4 5))) → (+ a 6 20)

LISP Programming Overview

Format:

C: printf("hello, world\n");

LISP: `(format t "hello, world ~%")`

Booleans and Equality:

Math	Lisp	Notes
False	nil	equivalent to empty list ()
True	t	or any non-nil value
¬a	(not a)	
a = b	(= a b)	numerical comparison
a = b	(eq a b)	same object ("physical equality")
a = b	(eql a b)	same object, same number and type, or same character
a = b	(equal a b)	eql objects, or lists/arrays with equal elements
a = b	(equalp a b)	= numbers, or same character (case-insensitive), or recursively-equalp con cells, arrays, structures, hash tables
a ≠ b	(= a b)	numerical inequality
a ≠ b	(not (eq a b))	and similarly for other equality functions

Relations and operators are what you expect it to be

(or a b), (+ 2 3), (< 4 5), etc...

Function Definition

```
(defun function_name (arguments)
    (+ n 1))
```

Conditionals

If statements:

```
(if (clause)
    true
    false)
```

Conditional statement (similar to switch cases)

```
(cond
    ((clause 1) (do this))
    ((clause 2) (do this)))
```

Local Variables

LET and LET* create and initialize new local variables. LET operates in "parallel" and LET* operates sequentially.

```
(let ((a 0)) [operation])
;; If the operation had two things it were doing, it would do both at the same time


(let* ((a 0)) [operation])
;; If the operation had two things it were doing, it would do the first, and then the second
```

Example:

```
(let ((a 1))
    (let ((a 2) (b a))
        (print (list a b))
    )
)

;; Output would be (2 1)


(let ((a 1))
    (let* ((a 2) (b a))
        (print (list a b))
    )
)
;; Output would be (2 2)
```

Implementation Details