

CS 2740 Knowledge Representation

Lecture 2

Introduction to LISP

Milos Hauskrecht

milos@cs.pitt.edu

5329 Sennott Square

LISP language

LISP: LISt Processing language

- An AI language developed in 1958 (J. McCarthy at MIT)
- Special focus on symbolic processing and symbol manipulation
 - Linked list structures
 - Also programs, functions are represented as lists
- At one point special LISP computers with basic LISP functions implemented directly on hardware were available (Symbolics Inc., 80s)

LISP today:

- Many AI programs now are written in C,C++, Java
 - List manipulation libraries are available

LISP language

LISP Competitors:

- Prolog, Python
- but LISP keeps its dominance among high level (AI) programming languages

Current LISP:

- Common Lisp
- Scheme

are the most widely-known general-purpose Lisp dialects

Common LISP:

- Interpreter and compiler
- CLOS: object oriented programming

LISP tutorial

Syntax:

- Prefix notation
 - Operator first, arguments follow
 - E.g. (+ 3 2) adds 3 and 2

A lot of parentheses

- These define lists and also programs
- Examples:
 - (a b c d) is a list of 4 elements (atoms) a,b,c,d
 - (defun factorial (num)
 (cond ((<= num 0) 1)
 (t (* (factorial (- num 1)) num))
))

LISP tutorial: data types

Basic data types:

- **Symbols**

- a
- john
- 34

- **Lists**

- ()
- (a)
- (a john 34)
- (lambda (arg) (* arg arg))

LISP tutorial

For each symbol lisp attempts to find its value

> (setq a 10) ;; sets a value of symbol a to 10

10

> a ;; returns the value of a

10

Special symbols:

> t ;; true

T

> nil ;; nil stands for false or

NIL

> () ;; an empty list

NIL

LISP tutorial

Lists represent function calls as well as basic data structures

> (factorial 3)

6

> (+ 2 4)

6

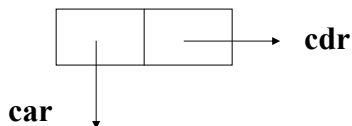
> (setq a '(john peter 34)) ;; quote means: do not eval the argument
(john peter 34)

> (setq a '((john 1) (peter 2)))
((john 1) (peter 2))

LISP tutorial: lists

List representation:

- A singly linked list



> (setq a '(john peter))
(john peter)

> (car a)
john

> (cdr a)
(peter)

LISP tutorial: list

List building functions

```
> (cons 'b nil) ;; quote means: do not eval the argument
(b)
> (setq a (cons 'b (cons 'c nil))) ;; setq a is a shorthand for set 'a
(b c)
> (setq v (list 'john 34 25))
(john 34 25)
> (setq v (list a 34 25))
((b c) 34 25)
> (append '(1 2) '(2 3))
(1 2 2 3)
```

LISP tutorial

List copying

```
> (setq foo (list 'a 'b 'c))
(a b c)
> (setq bar (cons 'x (cdr foo)))
(x b c)
> foo
(a b c) ;; (cdr foo) makes a copy of the remaining list before
cons
> bar
(x b c)
• Car and cdr operations are nondestructive.
```

LISP tutorial: lists

```
> (setq bar '(a b c))
(a b c)
> (setq foo (cdr bar))
(b c)
> (rplaca foo 'u) ;; replaces car component of foo (destructive op)
(u c)
> foo
(u c)
> bar
(a u c)
> (rplacd foo '(v)) ;; replaces cdr component of foo (destructive)
(u v)
> bar
(a u v)
```

LISP tutorial

The same effect as with rplaca and rplacd can be achieved with setf

```
> (setq bar '(a b c))
(a b c)
> (setq foo (cdr bar))
(b c)
> (setf (cadr bar) 'u)
u
> bar
(a u c)
> foo
(u c)
```

LISP tutorial

Evaluation rules:

- A symbol value is sought and substituted
- A quoted value is kept untouched

```
> (setq a 12)
12
```

```
> (setq b (+ a 4))
16
```

```
> (setq b '(+ a 4))
(+ a 4)
```

```
> (eval b)           ;; explicit evaluation call
16
```

LISP tutorial: functions and predicates

Some useful functions and predicates:

```
> (setq a '(1 2 3 4 5))
(1 2 3 4 5)
```

```
> (length a) ;; gives the list length of the argument
5
```

```
> (atom 'a) ;; checks if the argument is an atom
T
```

```
> (atom a)
NIL
```

```
> (listp 'a) ;; checks if the argument is a list
NIL
```

```
> (listp a)
T
```

LISP tutorial: function definition

Definition of a function

```
(defun <f-name> <parameter-list> <body>)
```

```
>(defun square (x)
```

```
  (* x x))
```

```
  SQUARE
```

```
>(square 2)
```

```
4
```

```
>(square (square 2))
```

```
16
```

LISP tutorial

Definition of a function

```
(defun <f-name> <parameter-list> <body>)
```

<body> can be a sequence of function calls, the function returns the value of the last call in the sequence

```
> (defun foo (a)
```

```
  (setq b (+ a 1))
```

```
  (setq c (+ a 2))
```

```
  c)
```

```
  FOO
```

```
> (foo 2)
```

```
4
```


LISP tutorial: conditionals

Cond statement: sequentially tests conditions, the call associated with the first true condition is executed

```
> (defun abs (a)
  (cond ((> a 0) a)
        (t (- a))))
```

ABS

```
> (abs 2)
```

2

```
> (abs -3)
```

3

LISP tutorial

if statement:

(if <test> <then> <else>)

```
> (defun abs (a)
  (if (> a 0) a (- a)))
```

ABS

```
> (abs 2)
```

2

```
> (abs -3)
```

3

LISP tutorial: equality

4 equality predicates: =, equal, eq, eql

> (= 2 4/2) ;; used for numerical values only

T

> (setf a '(1 2 3 4))

(1 2 3 4)

>(setf b '(1 2 3 4))

(1 2 3 4)

>(setf c b)

(1 2 3 4)

> (equal a b) ;; equal is true if the two objects are isomorphic

T

> (equal c b)

T

LISP tutorial: equalities

>(eq a b) ;; eq is true if the two arguments point to the same object

NIL

>(eq b c)

T

LISP tutorial: nil

Nil represents False and an empty list

> (null nil) ; tests if the argument is NIL

T

> (null ())

T

> (null '(a b))

NIL

> (not '(a b))

NIL

LISP tutorial: functions

Logical operators: and, or

> (and NIL T)

NIL

> (and T 2 3)

3

> (or nil (= 5 4))

NIL

> (or nil 5)

5

LISP tutorial: recursion

Recursive function definitions are very common in LISP

```
> (defun factorial (num)
  (cond ((<= num 0) 1)
        (t (* (factorial (- num 1)) num))
        ))
FACTORIAL
> (factorial 4)
24
```

LISP tutorial: recursion

Recursive function definitions are very common in LISP

```
> (defun check_lists (lis)
  (cond ((null lis) nil)
        (t (cons (listp (car lis)) (check_lists (cdr lis))))))
CHECK_LISTS
> (check_lists (list 'a '(1 2) 3 '(a b c) '(a)))
(NIL T NIL T T)
```

LISP tutorial: local and global variables

```
> (setq a 12)
12
> (defun foo (n)
  (setq a 14)
  (+ n 2))
FOO
> a
12
> (foo 3)
5
> a
14
```

LISP tutorial: local variables

Defining local variables with let

```
> (setq a 7) ;store a number as the value of a symbol
7
> a ;take the value of a symbol
7
> (let ((a 1)) a) ;binds the value of a symbol temporarily to 6
1
> a ;the value is 7 again once the let is finished
7
> b ;try to take the value of a symbol which has no value
Error: Attempt to take the value of the unbound symbol B
```

LISP tutorial: local variables

Defining local variables with let and let*

```
> (let ((a 5)          ;; binds vars to values locally
        (b 4))
    (+ a b))
9
> (let* ((a 5)         ;; binds vars sequentially
         (b (+ a 2))
         (+ a b))
    12
```

LISP tutorial: functions revisited

Standard function – all parameters defined

```
(defun fact (x)
  (if (> x 0)
      (* x (fact (- x 1)))
      1))
```

But it is possible to define functions:

- with variable number of parameters,
- optional parameters and
- keyword-based parameters

LISP tutorial: functions revisited

Functions with optional parameters

```
> (defun bar (x &optional y) (if y x 0))
```

BAR

```
> (defun baaz (&optional (x 3) (z 10)) (+ x z))
```

BAAZ

```
> (bar 5)
```

0

```
> (bar 5 t)
```

5

```
> (baaz)
```

13

```
> (baaz 5 6)
```

11

```
> (baaz 5)
```

15

LISP tutorial: functions revisited

Functions with variable number of parameters

```
> (defun foo (x &rest y) y) ;; all but the first parameters are put  
;; into a list
```

FOO

```
> (foo 3)
```

NIL

```
> (foo 1 2 3)
```

(2 3)

```
> (foo 1 2 3 4 5)
```

(2 3 4 5)

LISP tutorial: functions revisited

Functions with 'keyword' parameters

```
> (defun foo (&key x y) (cons x y))
FOO
> (foo :x 5 :y '(3))
(5 3)
> (foo :y '(3) :x 5)
(5 3)
> (foo :y 3)
(NIL 3)
> (foo)
(NIL)
```

LISP tutorial: arrays

List is a basic structure; but arrays and structures are supported

```
> (setf a (make-array '(3 2)) ;; make a 3 by 2 array
#2a((NIL NIL) (NIL NIL) (NIL NIL))
> (aref a 1 1)
NIL
> (setf (aref a 1 1) 2)
2
> (aref a 1 1)
2
```


LISP tutorial: structures

```
>(defstruct weather
  temperature
  rain
  pressure)
WEATHER
> (setf a (make-weather)) ;; make a structure
#s(WEATHER :TEMPERATURE NIL :RAIN NIL :PRESSURE NIL)
> (setf a (make-weather :temperature 35))
#s(WEATHER :TEMPERATURE 35 :RAIN NIL :PRESSURE NIL)
> (weather-temperature a) ;; access a field
35
> (weather-rain a)
NIL
> (setf (weather-rain a) T) ;; set the value of a field
T
> (weather-rain a)
T
```

LISP tutorial: iterations

Many ways to define iterations

Commands:

- loop
- dolist
- dotimes
- do, do*

Also we can write compactly the code for repeated application of function to elements of the list:

- mapc, mapcar

LISP tutorial: iterations

Iterations: loop

```
> (setq a 4)
4
> (loop (setq a (+ a 1))
      (when (> a 7) (return a))) ;; return exists the loop
8
> (loop (setq a (- a 1))
      (when (< a 3) (return)))
NIL
```

LISP tutorial: iterations

Iterations: dolist

```
> (dolist (x '(1 2 3 4)) (print x))
1
2
3
4
NIL ;; NIL is returned by dolist
>
```

LISP tutorial: iterations

Iterations: dotimes

```
> (dotimes (i 4) (print i)) ;; starts from 0 and continues till  
limit 4
```

0

1

2

3

4

```
NIL ;; returns NIL
```

LISP tutorial: iterations

Iterations: do

```
> (do ((x 1 (+ x 1)) ;; variable, initial value, next cycle update  
      (y 1 (* y 2))) ;; the same  
      ((> x 5) y) ;; end condition, value do returns  
      (print (list x y)) ;; body of do – a sequence of operations  
      (print 'next))
```

(1 1)

NEXT

(2 2)

NEXT

(3 4)

NEXT

(4 8)

NEXT

(5 16)

NEXT

32

LISP tutorial: iterations

Iterations: do *

```
> (do* ((x 1 (+ x 1)) ;; variable, initial value, next cycle update
        (y 1 (* x 2))) ;; <<< --- update based on x
      ((> x 5) y) ;; end condition, value do returns
      (print (list x y)) ;; body of do – a sequence of operations
      (print 'next))
(1 1)
NEXT
(2 4)
NEXT
(3 6)
NEXT
(4 8)
NEXT
(5 10)
NEXT
12
```

LISP tutorial: mapcar

Repeated application of a function to elements of the list

```
> (mapcar #'oddp '(1 2 3 4 5)) ;; named function
(T NIL T NIL T)
> (mapcar #'(lambda(x) (* x x)) '(1 2 3 4 5)) ;;temp function
(1 4 9 16 25)
```

LISP tutorial

Evals and function calls

- A piece of code can be built, manipulated as data
- What if we want to execute it?

```
> (setq b '(+ a 4))
```

```
  (+ a 4)
```

```
> (eval b)           ;; explicit evaluation call
```

```
  16
```

```
> (funcall #' + 2 4) ;; calls a function with args
```

```
  6
```

```
> (apply #' + 2 '(5 6)) ;; calls a function with args  
                          (last args as a list)
```

```
  13
```

LISP tutorial: input/output

You can input/output data to:

- standard input/output,
- string or
- file

A number of functions supported by the Lisp:

- (read) ;; reads the input from the standard input
- (print 'a) ;; prints to the standard output
- (scanf ...) (printf ...) (format ...) for formatted input and output
- (open ..) (close ..) for opening and closing the files
- (load ..) **reads and executes the file**

LISP tutorial: program calls

Assume you have your lisp code ready in the .lisp file

This is how you load it

```
(load "~/private/lsp/file-to-load.lisp")
```

... and you can call another load from it as well

Running LISP for CS Students

- Remotely login via ssh to elements.cs.pitt.edu
- LISP is installed in the following directory:
`/usr/local/contrib/cmuc1-19d/`
- You can run lisp from linux by typing `/usr/local/contrib/cmuc1-19d/bin/lisp`
 - You may want to provide a path to the lisp directory so that the executable is seen from anywhere
 - To do this, edit your `.cshrc` custom file under your home directory and add the following line:
`set path = ($path /usr/local/contrib/cmuc1-19d/bin)`
- Use the command `(quit)` to quit LISP

Running LISP for Non-CS Students

- Remotely login via ssh to `unixs.cis.pitt.edu`
- LISP is installed in the following directory: `/usr/pitt/franz-lisp/`
- You can run lisp from unix by typing: `/usr/pitt/franz-lisp/mlisp`
 - You may want to provide a path to the lisp directory so that the executable is seen from anywhere
 - To do this, edit your `.cshrc` file under your home directory and add the following line:
`set path = ($path /usr/pitt/franz-lisp)`
 - If `.cshrc` is read-only, then add write permission with the command: `chmod u+w .cshrc`
- Use the command `(exit)` to quit LISP