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))

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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

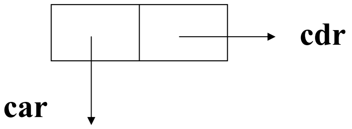
```
> (factorial 3)
  6
> (+ 2 4)
  6

> (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)
```

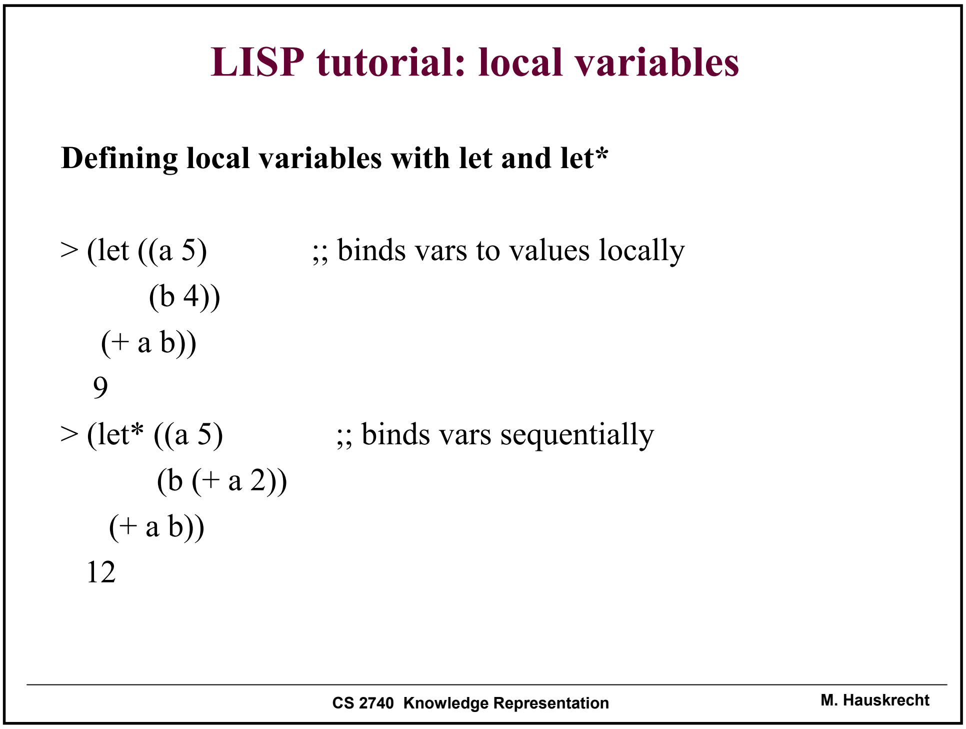
LISP tutorial: local and global variables

```
> (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

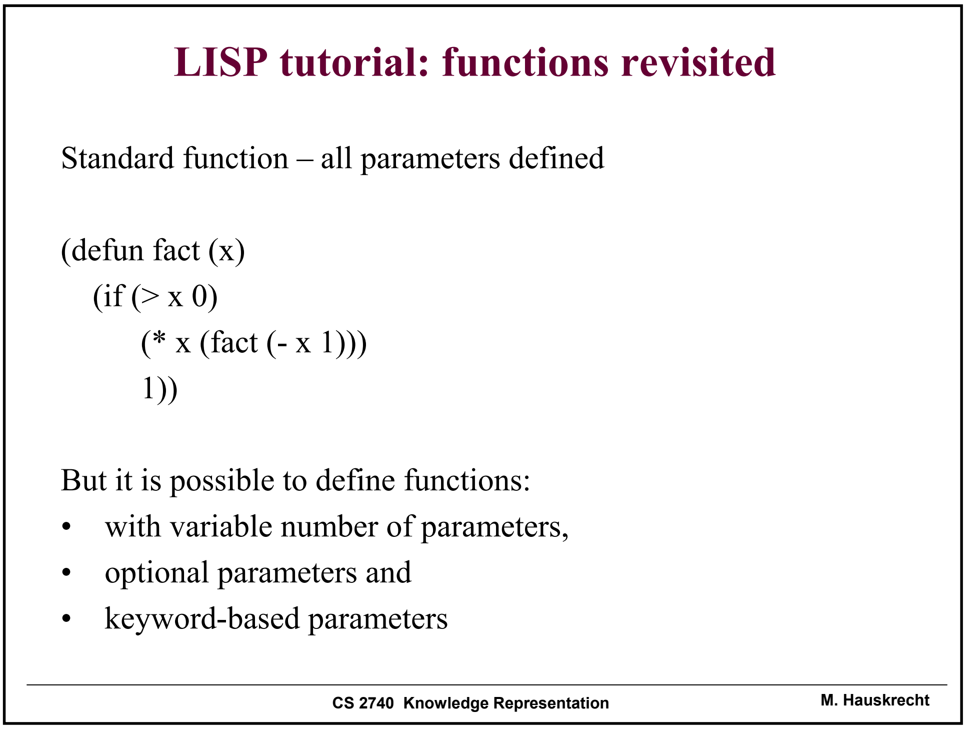
```
> (setq a 7)      ;store a number as the value of a symbol
 7
> a               ;take the value of a symbol
 7
> (let ((a 1)) a)   ;binds the value of a symbol temporarily to 6
 1
> a               ;the value is 7 again once the let is finished
7
> b               ;try to take the value of a symbol 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/cmucl-19d/
- You can run lisp from linux by typing /usr/local/contrib/cmucl-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/cmucl-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