Lecture 2. Introduction to Lisp

CS 161: Fundamentals of AI

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What is Lisp

- Originally specified in 1958 by John McCarthy, Lisp is the second-oldest high-level programming language
- Lisp has changed since its early days, and many dialects have existed over its history. Today, one of the best-known general-purpose Lisp dialects is Common Lisp.

Why do we use it in this class?

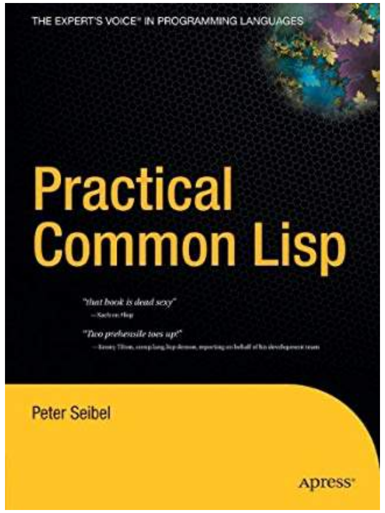
- Why do we use it in this class?
  - Lisp is the AI language since 1980s
  - Lisp is popular for traditional AI programming because it supports symbolic computation very well
  - “If you think the greatest pleasure in programming comes from getting a lot done with code that simply and clearly expresses your intention, then programming in Common Lisp is likely to be about the most fun you can have with a computer.” -- `Peter Seibel`, author of `Practical Common Lisp’

Common Lisp

- The modern, multi-paradigm, high-performance, compiled, ANSI-standardized, most prominent descendant of the long-running family of Lisp programming languages.
- Object oriented programming and fast prototyping capabilities

Useful Resources

- CLISP
  - CLISP implements the language described in the ANSI Common Lisp standard with many extensions.
  - https://clisp.sourceforge.io/
  - You can also access it from SEASnet
- Try Lisp online:
  - https://jscl-project.github.io/
- Portacle (if you don't have seasnet account yet)
  - All-in-one IDE (Windows, Mac OS X, Linux)
  - https://portacle.github.io/
- ***Practical Common Lisp*** **(Book)**
  - http://www.gigamonkeys.com/book/



CLISP on SEASnet

```
ssh -X lnxsrv.seas.ucla.edu -l yourseasaccountname
clisp
```

```
Windows: use putty
```

Syntax

Two fundamental pieces

- ATOM
- S-EXPRESSION.

Atom

comment

```
30              ; => 30
"Hello!"        ; string

t               ; denoting true
nil             ; false; the empty list: ()

:A              ; symbol
A               ; Error. Not defined
```

any non-NIL value is true!

Atom

```
9999999999999999999999 ; integer
#b111                  ; binary => 7
#x111                  ; hexadecimal => 273
3.14159s0              ; single
3.14159d0              ; double
1/2                    ; ratios
#C(1 2)                ; complex numbers
```

s-expression: super simple, super elegant

```
(f x y z ...)
```

function arguments

```
(+ 1 2 3 4)    ; 1+2+3+4 => 10
```

Use `quote` or apostrophe `'` to prevent it from being evaluated

```
'(+ 1 2)            ; => (+ 1 2)
(quote (+ 1 2))     ; => (+ 1 2)
'(1 2 3)            ; list (1 2 3)
```

Basic arithmetic operations

- `(+ 1 1)                ; => 2`
- `(- 8 1)                ; => 7`
- `(* 10 2)               ; => 20`
- `(expt 2 3)             ; => 8`
- `(mod 5 2)              ; => 1`
- `(/ 35 5)               ; => 7`
- `(/ 1 3)                ; => 1/3`
- `(+ #C(1 2) #C(6 -4))   ; => #C(7 -2)`

Booleans and Equality

```
(not nil)              ; => T
(and 0 t)              ; => T
(or 0 nil)             ; => 0
(and 1 ())             ; => nil
```

empty list

Operator first, arguments follow!

Booleans and Equality

compare numbers

```
(= 3 3.0)                ; => T
(= 2 1)                  ; => NIL
```

compare object identity

```
(eql 3 3)                ; => T
(eql 3 3.0)              ; => NIL
(eql (list 3) (list 3))  ; => NIL
(eql 'a 'a)              ; => T
```

compare lists, strings

```
(equal (list 'a 'b) (list 'a 'b)) ; => T
(equal (list 'a 'b) (list 'b 'a)) ; => NIL
```

Strings

type

```
(concatenate 'string "Hello," "world!") ; => "Hello,world!"

(format nil "Hello, ~a" "Alice") ; returns "Hello, Alice"
(format t "Hello, ~a" "Alice")   ; returns nil. formatted string
                                   goes to standard output

(print "hello")    ; value is returned and printed to std out
(+ 1 (print 2))    ; prints 2. returns 3.
```

Variables

- global (dynamically scoped) variable
- The variable name can use any character except: ()",'`;#|\

```
(defparameter age 35)
age                          ; => 35

(defparameter *city* "LA")
*city*                       ; => "LA"
```

Variables

```
(defparameter age 35)   ; age => 35
(defparameter age 60)   ; age => 60

(defvar newage 20)      ; newage => 20
(defvar newage 60)      ; newage => 20
```

defvar does not change the value of the variable!

```
(setq newage 30)        ; newage => 30
```

Local variable

```
(let ( (a 1) (b 2) )    ; binding
     (+ a b)            ; body
)
```

You will NOT be allowed to set global variables in your homework!

let only

A lot of parentheses! These define lists and also programs

Lists

- Linked-list data structures
- Made of CONS pairs

```
(cons 1 2)                       ; => '(1 2)
(cons 3 nil)                     ; => '(3)
(cons 1 (cons 2 (cons 3 nil)))   ; => '(1 2 3)
(list 1 2 3)                     ; => '(1 2 3)
(cons 4 '(1 2 3))                ; => '(4 1 2 3)
(cons '(4 5) '(1 2 3))           ; =>  ?
```

Lists

```
(cons 1 (cons 2 (cons 3 nil)))      ; => '(1 2 3)
(list 1 2 3)                        ; => '(1 2 3)
(cons 4 '(1 2 3))                   ; => '(4 1 2 3)
(cons '(4 5) '(1 2 3))              ; => '((4 5) 1 2 3)

(append '(1 2) '(3 4))              ; => '(1 2 3 4)
(append 1 '(1 2))                   ; ERROR!
(concatenate 'list '(1 2) '(3 4))   ; => '(1 2 3 4)

(car '(1 2 3 4))                    ; => 1
(cdr '(1 2 3 4))                    ; => '(2 3 4)
car and cdr should be used for list
```

Functions

- Define a function

```
(defun hello (name) (format nil "Hello, ~A" name))
```

- Call the function

```
(hello "Bob")              ; => "Hello, Bob"
```

Control Flow

```
(if (equal *name* "bob")    ; test expression
    "ok"                    ; then expression
    "no")                   ; else expression
```

- Chains of tests: cond

```
(cond ((> *age* 20) "Older than 20")
      ((< *age* 20) "Younger than 20")
      (t "Exactly 20"))

(cond ((> *age* 20) "Older than 20")
      ((< *age* 20) "Younger than 20"))     ; returns NIL when *age*=20
```

Programming Practice!

- `Factorial`
- `compute list length`
- `find kth element`
- `check if list contains a number`

Recursion - factorial

```
(defun factorial (n)
  (if (< n 2)
    1                              ; returns 1 when n<2
    (* n (factorial (- n 1)))       ; when n>=2
   )
)

(factorial 5)                      ; => 120
```

Recursion – compute list length (top-level)

```
'((a b) (c (d 1)) e)  => 3

(defun listlength (x)
      (if (not x)                   ; base case: empty list
            0
            (+ (listlength (cdr x)) 1)
      )                        '(1 2 3 4) -> '(2 3 4)
)
```

Recursion – compute list length (deep)

```
'((a b) (c (d 1)) e)  => 6

(defun deeplength (x)
      (cond ((not x) 0)         ; empty list. returns 0
             ((atom x) 1)       ; atom. returns 1
             (t (+ (deeplength (car x))   ; else
                   (deeplength (cdr x))
                )
             )
      )
)
```

Recursion – check if list contains an element

```
(defun contains (e x)
       (cond ((not x) nil)
             ((atom x) (equal e x))
             (t (or (contains e (car x)) (contains e (cdr x))))
       )
)

(contains 'a '((b a) (1 e c)))
```

Recursion – check if list contains a number

Consider this case: '((a b) (c (d 1)) e)

```
(defun contains_number (x)
       (if (atom x)              ; NIL if x is a list
           (numberp x)           ; numberp: check if x is a number
           (or (contains_number (car x))
                (contains_number (cdr x))    ; recursively flatten
           )
       )
)
```

Recursion – find kth element (top-level)

```
(defun find_kth (k x)
     (if  (= k 1)
          (car x)
          (find_kth (- k 1) (cdr x))
     )
)
```

How do we find kth element in the flattened list?

```
3, '((a b) (c (d 1)) e)    => c
```

Recursion – delete kth element

```
(defun delete_kth (k x)
     (if  (= k 1)
          (cdr x)
          (cons (car x)
                   (delete_kth (- k 1) (cdr x))
          )
     )
)
```

Recursion

```
(defun x () (x))
```

This runs forever!

Iteration

```
(loop for x in '(1 2 3 4 5)
      do (print x) )
std out:
1
2
3
4
5
return:
NIL
```

Iteration

```
(loop for x in '(1 2 3 4 5)
      for y in '(1 2 3 4 5)
      collect (+ x y)
)                                   ; => (2 4 6 8 10)

(loop for x in '(1 2 3 4 5)
      for y in '(1 2 3 4)
      collect (+ x y)
)                                   ; => ?
```

Iteration

```
(loop for x in '(1 2 3 4 5)
      for y in '(1 2 3 4 5)
      collect (+ x y)
)                                    ; => (2 4 6 8 10)

(loop for x in '(1 2 3 4 5)
      for y in '(1 2 3 4)
      collect (+ x y)
)                                    ; => (2 4 6 8)
```

Iteration

```
(loop for x from 1 to 5
      for y = (* x 2)
      collect y
)                                    ; => (2 4 6 8 10)
```

How do we compute factorial in loop?

Iteration-factorial

```
(setf fact 1)
(defun factorial(n)
    (loop for x from 2 to n
          do(setf fact (* x fact))
          )
    (print fact)
)
```

Recursion is much more natural

Acknowledgment

- The slides are adapted from Shirley Chen.