Common Lisp II

Input and Output

- Print is the most primitive output function

```
> (print (list 'foo 'bar))
(FOO BAR)
(FOO BAR)
```

- The most general output function in CL is *format* which takes two or more arguments:
  - – the first indicates where the input is to be printed,
  - – the second is a string template,
  - – the remaining arguments are objects whose printed representations are to be inserted into the template:

```
> (format t “~A plus ~A equals ~A.~%” 2 3 (+  2  3))
2 plus 3 equals 5.
NIL
```

Read

- The standard function for input is *read*.
- When given no arguments, it reads from the default place, which is usually standard input.

```
> (defun  ask (string)
      (format  t  “~A”  string)
      (read))
ask
>  (ask  “How old are you? “)
How old are you?  29
29
```

Local Variables

- One of the most frequently used operators in CL is *let.*
- This allows local variables to be used in a function.
- A let expression has two parts.
  - – First comes a list of instructions for creating variables, each of the form *var* or *(var expression)*.

    Local variables are valid within the body of the let.
  - – After the list of variables and values comes the body of expressions, which are evaluated in order.

```
> (let ((x 100) (y 200))
   (print (+ x y))
    (setq x 200)
    (print (+ x y))
    ‘foo)
300
400
foo
```

A let example

```
> (defun  ask-number  ()
     (format t  “Please enter a number. “)
     (let ((val  (read)))
        (if  (numberp val)
             val
              (ask-number))))
ASK-NUMBER
> (ask-number)
Please enter a number.  number
Please enter a number.  (this is a number)
Please enter a number.  52
52
```

Global variables

- Global variables are visible throughout the program.
- Global variables can be created by giving a symbol and a value to *defparameter* or *defvar*.

```
> (defparameter *foo* 1)
*FOO*
> *foo*
1
> (defvar *bar* (+ *foo* 1))
*BAR*
> *bar*
2
> (defvar *bar* 33)
*BAR*
> *bar*
2
```

Note: (*defparameter v e)* creates a global variable named v and sets its value to be e.

(*defvar v e)* is just like defparameter if no global variable named v exists. Otherwise it does nothing.

Global constants

- You can define a global constant, by calling *defconstant*.

```
> (defconstant +limit+  100)
+LIMIT+
> (setf +limit+ 99)
*** - SETQ: the value of the constant +LIMIT+ may
  not be altered
1. Break [5]>
```

- The plus-*something*-plus is a lisp convention to identify symbols as constants. Just like star-*something*-star is a lisp convention to identify global variables.

When in doubt

- When in doubt about whether some symbol is a global variable or constant, use *boundp*.

```
>  (boundp  ‘*foo*)
T
>  (boundp  ‘fishcake)
NIL
```

Assignment

- There are several assignment operators in Common Lisp: set, setq and setf
- the most general assignment operator is *setf*.
- We can use it to assign both local and global variables:

```
> (setf *blob* 89)
89
> (let ((n 10))
     (setf n 2)
     n)
2
```

Setf

- You can create global variables implicitly just by assigning them values.

```
> (setf  x  (list ‘a ‘b ‘c))
(A B C)
```

- However, it is better lisp style to use defparameter to declare global variables.
- You can give setf any even number of arguments:

```
(setf  a  1 b  2 c  3)
```

is the same as:

```
(setf a 1)
(setf b 2)
(setf c 3)
```

- You can do more than just assign values to variables with setf.
- The first argument to setf can be an expression as well as a variable name.
- In such cases, the value of the second argument is inserted in the *place* referred to by the first:

```
> (setf (car x) ‘n)
N
>
(N B C)
```

Setf

```
> (setq a (make-array 3))
#(NIL NIL NIL)
> (aref a 1)
NIL
> (setf (aref a 1) 3)
3
> a
#(NIL 3 NIL)
> (aref a 1)
3
> (defstruct foo bar)
FOO
>
```

```
(setq a (make-foo))
#s(FOO :BAR NIL)
> (foo-bar a)
NIL
> (setf (foo-bar a) 3)
3
> a
#s(FOO :BAR 3)
> (foo-bar a)
3
```

Functional programming

- *Functional programming* means writing programs that work by returning values, instead of by modifying things.
- It is the dominant programming paradigm in Lisp.
- Must built-in lisp functions are meant to be called for the values they return, not for side-effects.

Examples of functional programming

- The function *remove* takes an object and a list and returns a new list containing everything but that object:

```
> (setf  lst  ‘(b u t t e r))
(B U T T E R)
> (remove ‘e lst)
(B U T T R)
```

- Note: remove does not remove an item from the list! The original list is untouched after the call to remove:

```
> lst
(B U T T E R)
```

- To actually remove an item from a list you would have to use setf:

```
> (setf  lst  (remove ‘e lst))
```

- Functional programming means, essentially, avoiding setf, and other assignment macros.

How remove could be defined

Here’s how remove could be defined:

```
(defun remove (x list)
  (cond ((null list) nil)
          ((equal x (car list))
            (remove x (cdr list)))
          (t (cons (car list) (remove x (cdr list))))))
```

Note that it “copies” the top-level of the list.

Iteration

- When we want to do something repeatedly, it is sometimes more natural to use iteration than recursion.
- This function uses *do* to print out the squares of the integers from *start* to *end*:

```
(defun  show-squares  (start  end)
   (do  ((i  start  (+  i  1)))
        ((>  i  end)  ‘done)
        (format t  “~A  ~A~%”  i (* i i))))
```

do

- The *do* macro is CL's fundamental iteration operator.
- Like *let*, *do* can create variables, and the first argument is a list of variable specifications. Each element is of the form: (*var initial update*) where *variable* is a symbol, and *initial* and *update* are expressions.
- The second argument to *do* should be a list containing one or more expressions.
  - The first expression is used to test whether iteration should stop. In the case above, the test expression is (> i end).
  - The remaining expression in this list will be evaluated in order when iteration stops, and the value of the last will be returned as the value of the *do*, *done* in this example.
- The remaining arguments to *do* comprise the body of the loop.

Dolist

- CL has a simpler iteration operator for handling lists, *dolist*.

```
(defun len (lst)
  "I calculate the length of lst"
   (let ((l 0))
      (dolist (obj lst) (setf l (+ l 1)))
      l))
```

- Here dolist takes an argument of the form (*variable expression*), followed by a body of expressions.
- The body will be evaluated with *variable* bound to successive elements of the list returned by expression.

eval

- You can call Lisp's evaluation process with the eval function.

```
> (setf s1 '(cadr '(one two three)))
(CADR '(ONE TWO THREE))
> (eval s1)
TWO
> (eval (list 'cdr (car '((quote (a . b)) c))))
B
```

Functions as objects

- In lisp, functions are regular objects, like symbols, or strings, or lists.
- If we give the name of a function to *function*, it will return the associated object.
- Like *quote*, *function* is a *special operator*, so we don't have to quote the argument:

```
> (defun add1 (n) (+ n 1))
ADD1
> (function +)
#<SYSTEM-FUNCTION +>
> (function add1)
#<CLOSURE ADD1 (N) (DECLARE (SYSTEM::IN-DEFUN
   ADD1)) (BLOCK ADD1 (+ N 1))>
```

- Just as we can use ‘ as an abbreviation for *quote*, we can use #’ as an abbreviation for *function*:

```
> #’+
#<SYSTEM-FUNCTION +>
```

- This abbreviation is known as sharp-quote.
- Like any other kind of object, we can pass functions as arguments.
- One function that takes a function as an argument is *apply*.

Apply

- *Apply* takes a function and a list of arguments for it, and returns the result of applying the function to the arguments:

```
> (apply  #’+  ‘(1  2  3))
6
```

- It can be given any number of arguments, so long as the last is a list:

```
> (apply  #’+  1  2  ‘(3  4  5))
15
```

- A simple version of apply could be written as follows

```
(defun apply (f list) (eval (cons f list)))
```

Funcall

- The function *funcall* is like *apply* but does not need the arguments to be packaged in a list:

```
>  (funcall  #’+  1  2  3)
6
```

- It could be written as:

```
(defun funcall (f &rest args)
  (eval (cons f args)))
```

Lambda

- The *defun* macro creates a function and gives it a name.
- However, functions don’t have to have names, and we don’t need *defun* to define them.
- We can refer to functions literally by using a *lambda expression*.

Lambda expression

- A *lambda expression* is a list containing the symbol *lambda*, followed by a list of *parameters*, followed by a *body* of zero or more expressions:

```
> (setf f (lambda (x) (+ x 1)))
#<CLOSURE :LAMBDA (X) (+ X 1)>
> (funcall f 100)
101
```

- A lambda expression can be considered as the name of a function.
- Like an ordinary function name, a lambda expression can be the first element of a function call:

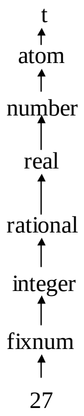
```
> ((lambda  (x)  (+  x  100))  1)
101
```

- and by affixing a sharp-quote to a lambda expression, we get the corresponding function:

```
> (funcall  #’(lambda (x)  (+  x 100))
                1)
101
```

Types

- In CL *values* have types, not *variables*.
- You don’t have to declare the types of variables, because any variable can hold objects of any type.
- Though type declaration is never required, you may want to make them for reasons of efficiency.
- The built-in CL types form a hierarchy of subtypes and supertypes.
- The type *t* is the supertype of all types, so everything is of type *t*.



t ↑ atom ↑ number ↑ real ↑ rational ↑ integer ↑ fixnum ↑ 27

```
>  (typep  27 ‘t)
T
> (typep  27  ‘atom)
T
> (typep  27  ‘number)
T
> (typep  27  ‘real)
T
> (typep 27  ‘rational)
T
> (typep  27  ‘integer)
T
> (typep  27  ‘fixnum)
T
>  (typep  27  ‘vector)
NIL
```