

Language for 2016 - Common Lisp

John Cumming

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1 Introduction

I have chosen common lisp as my language to learn in more depth for 2016 as I have dabbled with it over the past year or so, along with clojure, another very good lisp based language.

I chose common lisp as a language as I prefer the syntax over clojure and because I believe it should be able to produce more efficient code as well as being able to produce stand alone binary files without the dependence on the JVM that clojure has.

I have no specific plan as to how this learning will pan out, other than I intend to dive a bit deeper than I have done in the past.

The tools I use for this learning are SBCL and GNU Emacs with Slime. This is all running under OS-X El Capitan on a Macbook pro.

The complete source code for this article can be found [here](#) and the article formatted as PDF [here](#). The org-mode file used to generate this web page and the lisp code can be found [here](#).

Some books I have on lisp can be found here.

I have inter-dispersed larger examples through the code that hopefully build on the sections that have preceded.

2 An Overview of Common Lisp Syntax

Common lisp has a simple syntax for processing lists delimited by '(' and ')'. The lisp processes a list by applying the the first item in the list as an operator and the rest as operands. Lists can be nested:

```
1 ;; Comments can be added using a semi colon
2 (+
3   (* 3 4)
4   (+ 2 3))
```

This code applies operand '+' to the result of applying operand '*' to 3 and 4, and the result of applying operand '+' to 2 and 3.

A list can be created as a just list of data, by using the 'quote' operand or by using a shortcut single quote, the following are both equivalent:

```
5 ;; The following lines are equivalent
6 (equal (quote (1 2 3 4))
7        '(1 2 3 4))
8 ;; => T
```

More details on collections can be found in `Collections`.

String are, like most languages, delimited with double quotes.

Backslashes are used as escape characters, much like other languages. However, the use of a vertical bar allows special characters to be used without escaping:

```
9 ;; The following items in the list are equivalent
10 (equal 'A\ (B\) '|A(B)|)
11 ;; => T
```

A hash symbol is a macro symbol, known as the dispatching macro character. There are many of these, for example:

```
12 ;; #' - function abbreviation
13 ;; #\ - character object
14 ;; ,#+ - read-time conditional
15 ;; #c - complex number
16 ;; #( - vector
```

More details can be found in [Macro Dispatching Characters](#).

A back quote can be used to allow a template to be used when generating code, with a comma used to evaluate a form and an '@' symbol used to splice a list into the template, for example:

```
17 (defparameter x '(a b c))
18 ;; x
19 '(x)
20 ;; => (x)
21 '(,x)
22 ;; => ((a b c))
23 '(,@x)
24 ;; => (a b c)
25 '(x ,x ,@x foo ,(cadr x) bar ,(cadr x) baz ,@(cdr x))
26 ;; => (x (a b c) a b c foo b bar (b c) baz b c)
```

This is used extensively when writing macros. For more information on macros see [Macros](#).

Colons are used in 2 situations. Firstly it can be used to indicate the package in which a symbol is defined:

```
27 ;; reset is a symbol in the network package
28 ;; (network:reset)
```

Packages are discussed in [Packages](#).

It can also be used to denote a keyword, which is a symbol that always evaluates to itself and is constant. For example:

```
29 (eq1 ':foo :foo)
30 ;; => T
```

Keywords are interned in the package KEYWORD and are automatically exported from it:

```
31 (eq1 keyword:foo :foo)
32 ;; => T
```

3 Example 1 - Sum of Square Errors

An equation that is used in regression algorithms is the sum of the square of errors for a given dataset and function being fitted to the data.

Given a data set of size m with a single input variable x and a single output value y for each item in the data set and a function that is an attempt to fit a function to the values:

$$y = f(x)$$

Then an error can be calculated based on the sum of the square of the individual errors, giving an estimate of how well fitted the function is to the data:

$$E = \sum_{n=0}^m (f(x_n) - y_n)^2$$

Using lisp, we can write some code that takes a data set, computes the error based on several functions:

```

33  ;; First declare some data
34  ;;
35  (defparameter data '((0.1 . 1.1)
36                        (0.9 . 3.2)
37                        (2.1 . 5.9)
38                        (3.2 . 7.2)
39                        (3.9 . 9.0)
40                        (5.1 . 11.2)))
41
42  ;; then some equations
43  ;;
44  (defparameter equation-list
45    (list #'(lambda (x) (+ 1 (* 2 x)))
46          #'(lambda (x) (+ 1 (* x x)))
47          #'(lambda (x) (+ 1 x))))
48
49  ;; now create a function that applies a function
50  ;; to a set of input data
51  ;;
52  (defun apply-function (f d)
53    (map 'list #'(lambda (x) (funcall f (car x))) d))
54
55  ;; A function that returns the error as the difference
56  ;; between two values squared
57  ;;

```

```

58 (defun square-error (test-data calc-data)
59   (expt (- test-data calc-data) 2))
60
61 ;; A function that returns the sum of square errors
62 ;; of a collection of data and the results
63 ;;
64 (defun sum-square-error (f test-data)
65   (reduce #'+
66           (map 'list
67                #'(lambda (test calc)
68                    (square-error (cdr test) calc))
69                test-data (apply-function f test-data))))
70
71 ;; Now we can run the sum of square errors across all equations
72 ;;
73 (map 'list #'(lambda (eq) (sum-square-error eq data))
74      equation-list)

```

0.7400005 320.44208 61.350002

The data is defined as a set of cons cells with the car equal to an x value and the cdr equal to a y value. This is the test data that will be used to check the equations. It uses defparameter, but could equally be defined inline at Line 73.

The equations are defined as a list of lambda functions modeling the following equations for fitting to the data:

$$y = 2x + 1$$

$$y = x^2 + 1$$

$$y = x + 1$$

Again, these could have been defined inline at the point of use.

The apply-function function takes a function as an argument and a collection of data as an alist and executes the function taking the car of each item in the alist as the x value to calculate the y value.

The square-error function takes a single test data y value and a single calculated value and calculates the square of the error.

The sum-square-error function takes a function f and applies the square-error function to each item in the test data and the corresponding calculated output as calculated by the function f.

The output is generated by applying the sum-square-error function to each equation using the test data.

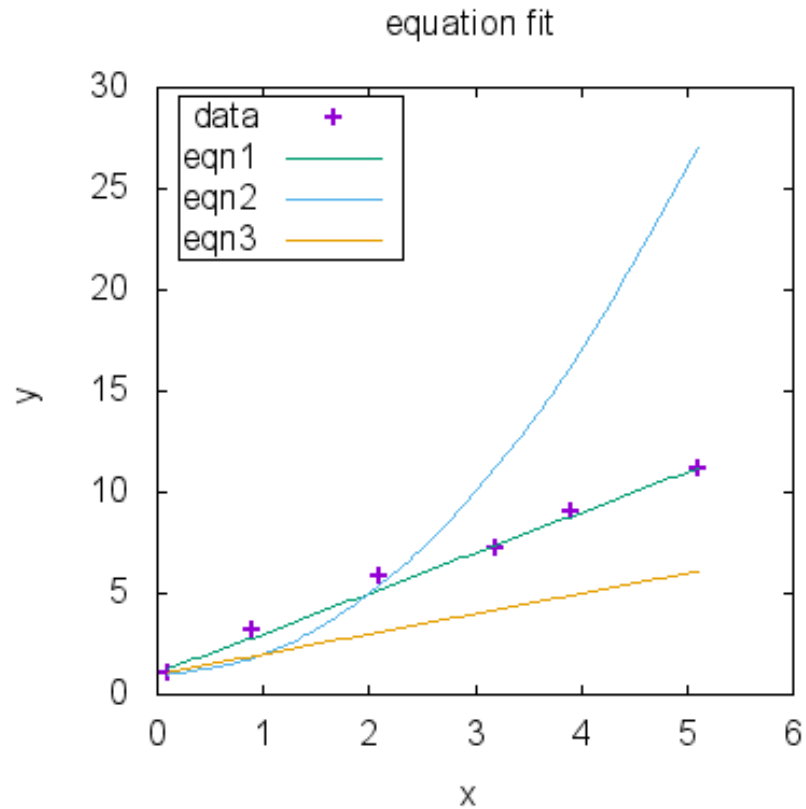
It can clearly be seen from both the results of the sum of square errors and the input data that eqn1 is the best fit.

To confirm this we can plot the data:

x	data	eqn1	eqn2	eqn3
0.1	1.1	1.3	1.01	1.1
0.9	3.2	2.8	1.81	1.9
2.1	5.9	5.2	5.41	3.1
3.2	7.2	7.4	11.24	4.2
3.9	9.0	8.8	16.21	4.9
5.1	11.2	11.2	27.01	6.1

using this gnuplot script:

```
set terminal png nocrop enhanced size 400,400
set key left box linestyle -1
set xlabel 'x'
set ylabel 'y'
set title 'equation fit'
plot data u 1:2 w p lw 2 title 'data', \
      data u 1:3 smooth csplines lw 1 title 'eqn1', \
      data u 1:4 smooth csplines lw 1 title 'eqn2', \
      data u 1:5 smooth csplines lw 1 title 'eqn3'
```



4 Core functions

- cons

cons is used to construct lists, it puts a new element at the end of the list, or can be used for creating a pair:

```

75 (cons 1 3)
76 ;; => (1 . 3)
77 (cons 3 nil)
78 ;; => (3)
79 (cons 5 '(1 2 3 4))
80 ;; => (5 1 2 3 4)

```

- car

Given a list car retrieves the first item in a list:


```
81 (car '(1 2 3 4))
82 ;; => 1
```

- cdr

Given a list cdr retrieves the remaining list after the first element

```
83 (cdr '(1 2 3 4))
84 ;; => (2 3 4)
```

- cadr / caddr etc

These can be nested to various levels for example:

```
85 (cadr '(1 2 3 5))
86 ;; => 2
87 (caddr '(1 2 3 4))
88 ;; => (3 4)
```

- lambda

lambda is used to create a function special form involving a lambda expression. The expression takes a lambda list and a form and returns a function:

```
89 (lambda (x) (+ 1 x))
90 ;; => #<FUNCTION (LAMBDA (X)) {10035B665B}>
```

- funcall

Funcall is used to call a function, which can be created with a lambda. However it becomes more useful when passing lambda expressions or functions as arguments (a little convoluted):

```
91 (funcall (lambda (x) (+ 1 x)) 3)
92 ;; => 4
93
94 (defun do-something (x a)
95   (funcall x a))
96 (do-something (lambda (x) (+ 1 x)) 2)
97 ;; => 3
```

- function

With the function function we can return a function from a function! This can be used to create a form of partial functions:

```

98 (defun multiplier (n)
99   (function (lambda (x) (* x n))))
100
101 (funcall (multiplier 3) 4)
102 ;; => 12
103
104 (defun doubler (n)
105   (funcall (multiplier 2) n))
106
107 (doubler 10)
108 ;; => 20

```

- apply

The apply function is very similar to funcall, except it takes a list as an argument. This means that it can be used when the number of arguments is unknown at compile time.

```

109 (apply #' + 100 '(4 5 6 7))
110 ;; => 122
111 (defun add-to-ten (&rest args)
112   (apply #' + 10 args))
113 (add-to-ten 1 2 3 4 5)
114 ;; => 25

```

- read

The read function reads a single s-expression, skipping whitespace and comments and returns the lisp object denoted by the s-expression.

```

115 ;; given a file code.lisp containing
116 ;;
117 ;; (1 2 3)
118 ;; 456
119 ;; "a string" ; this is a comment
120 ;; ((a b)
121 ;;  (c d))
122 ;;
123 (defparameter *s* (open "code.lisp"))
124 ;; => *S*
125 (read *s*)
126 ;; => (1 2 3)

```

```

127 (read *s*)
128 ;; => 456
129 (read *s*)
130 ;; => "a string"
131 (read *s*)
132 ;; ((A B) (C D))
133 (close *s*)
134 ;; => T

```

- eval

The eval function just evaluates a lisp expression. It is used in combination with read to execute lisp expressions:

```

135 (eval (+ 1 2))
136 ;; => 3
137 ;; given a file code.lisp with a line
138 ;; (+ 1 2)
139 (defparameter *s* (open "code.lisp"))
140 (eval (read *s*))
141 ;; => 3

```

- print

The print function prints the representation of a lisp object.

```

142 (print 2)
143 ;; 2
144 ;; => 2
145 (print (eval (+ 1 2)))
146 ;; 3
147 ;; => 3

```

- cond

The primary conditional statement in lisp is the cond function:

```

148 (defun get-type-name (a)
149   (cond ((null a) "null")
150         ((atom a) "atom")
151         ((listp a) "list")
152         (t "unknown")))
153 (get-type-name nil)

```

```

154 ;; => "null"
155 (get-type-name 1)
156 ;; => "atom"
157 (get-type-name '(1))
158 ;; => "list"

```

- quote

The quote function is described above.

- atom

The atom function is outlined below.

- null

The null function determines if a symbol is nil:

```

159 (null nil)
160 ;; => T
161 (null 1)
162 ;; => nil
163 (null '())
164 ;; => T

```

- set, setf and setq

set is the original lisp function. setf is a shorthand function meaning set field and setq a shorthand function meaning set quote. One can think of set as setting value of symbols and setf as setting the value of variables. setq is a macro allowing various setting of things.

```

165 ;; The following are all equivalent
166 (set (quote *foo*) 42)
167 (setf (symbol-value '*foo*) 42)
168 (set '*foo* 42)
169 (setq *foo* 42)
170 ;; assigning to data structure
171 (setf (car x) 42)
172 ;; some more examples
173 (set ls '(1 2 3 4)) ;; ERROR ls has no value
174 (set 'ls '(1 2 3 4)) ;; OK
175 (setq ls '(1 2 3 4)) ;; OK
176 (setf ls '(1 2 3 4)) ;; OK
177 (setf (car ls) 10) ;; ls -> '(10 2 3 4)

```

- defvar and defparameter

defvar and defparameter are very similar, both bind a value to a name. the difference is that defvar only binds the value if it is not already bound. However, the value can still be changed with setq:

```

178 (defvar *s* 2)
179 ;; => *S*
180 *S*
181 ;; => 2
182 (defvar *s* 3)
183 *S*
184 ;; => 2
185 (setq *s* 3)
186 *S*
187 ;; => 3
188 (defparameter *t* 2)
189 *t*
190 ;; => 2
191 (defparameter *t* 3)
192 *t*
193 ;; => 3

```

- defconstant

defconstant is similar to defparameter and defvar, except the value cannot be changed.

- defun

defun defines a function that can be called from other parts of code. They are the primary abstraction mechanism in lisp and are described below.

- defmacro

defmacro is used to define macros that are evaluated during compilation, they are discussed below.

- equality predicates

There are several equality operators in lisp that perform different functions:

(eq x y) is true if and only if x and y are identical objects.

(eql x y) is true if (eq x y) or x and y are numbers of the same type and have the same value, or are character objects that represent the same character.

(equal x y) is true if x and y are structurally similar (isomorphic). It is often the case that x and y will have the same printed representation.

(equalp x y) is true if (equal x y) is true or for numbers they have the same value even if they are different types or for characters that are equal but different case. For collections, (equalp x y) is true if equalp is true for every element in the collection.

5 Data Structures

5.1 Atoms

Atoms are things that are not cons cells, and can be tested using the atom predicate:

```
194 (atom 1)
195 ;; => T
196 (atom :test)
197 ;; => T
198 (atom nil)
199 ;; => T
200 (atom '())
201 ;; => T
```

However, they are not things that cannot be broken down any further:

```
202 (atom "text")
203 ;; => T
204 (atom #(1 2 3))
205 ;; => T
```

Symbols are atoms as well:

```
206 (defun test-atomicity (x) (atom x))
207 (atom 'test-atomicity)
208 ;; => T
```

And lambda expressions:

```

209 (atom (lambda (x) (atom x)))
210 ;; => T

```

Examples of some things that are not atoms:

```

211 (atom '(1 . 3))
212 ;; => NIL
213 (atom '(1 2 3))
214 ;; => NIL
215 (atom (cdr '(1 2 3)))
216 ;; => NIL

```

5.2 Sequences

Sequences are ordered lists of elements and can be manipulated by a variety of standard sequence functions. A sequence is either a vector or a list. Vectors are one dimensional arrays and Lists are linked lists made up of cons cells and are discussed here.

5.2.1 Arrays and Vectors

- simple array

Arrays are simple multi dimensional lists of fixed size with elements that are arranged sequentially, rather than as a linked list in the case of lisp lists:

```

217 ;; creates a 3 dimensional array with 10 elements in each dimensional
218 (defparameter *array* (make-array '(10 10 10)))
219 ;; creates an array with all elements initialised to 23
220 (defparameter *23-array* (make-array '(10 10) :initial-element 23))
221 ;; initialise with content
222 (defparameter *fib* (make-array '(5) :initial-contents '(1 2 3 5 8)))
223 ;; set a value of an array element
224 (setf (aref *23-array* 5 5) 7)
225 ;; an array with room for 2 elements, resizable but empty
226 (defparameter *resizable* (make-array '(2) :fill-pointer 0 :adjustable t))
227 (vector-push 'a *resizable*)
228 (vector-push 'b *resizable*)
229 (vector-push-extend 'c *resizable*)
230 *resizable*
231 ;; => #(A B C)

```

```

232 (vector-pop *resizeable*)
233 *resizeable*
234 ;; => #(A B)
235 (adjust-array *resizeable* '(2))

```

- bit vector

Bit vector are efficient containers for bits that can be manipulated with bitwise operations:

```

236 (bit-and #*1101000101000101 #*0100100010100101)
237 ;; = > #*0100000000000101

```

5.2.2 TODO Strings

A string is a specialized vector with elements of type character. All the sequence functions below can be applied to strings.

- Manipulating the case of a string

- string-upcase
- string-downcase
- string-capitalize
- nstring-upcase
- nstring-downcase
- nstring-capitalize

- Trimming strings

- string-trim
- string-left-trim
- string-right-trim

- Converting to and from strings

- intern
- symbol-name
- string
- coerce
- parse-integer

- read-from-string
- write-to-string
- Comparing strings
 - string=
 - string/=
 - string-equal
 - string-not-equal
 - string<
 - string>
 - string<=
 - string>=
 - string-lessp
 - string-greaterp
 - string-not-lessp
 - string-not-greaterp

5.2.3 Lists

- Cons Cells
- Proper List
- Dotted List
- Circular List

5.2.4 Manipulating Sequences

- concatenate
- copy-seq
- count
- count-if
- count-if-not
- delete

- delete-duplicates
- delete-if
- delete-if-not
- elt
- every
- fill
- find
- find-if
- find-if-not
- length
- map
- mapcar
- map-into
- merge
- mismatch
- notany
- notevery
- nreverse
- nsubstitute
- nsubstitute-if
- nsubstitute-if-not
- position
- position-if
- position-if-not

- reduce
- remove
- remove-duplicates
- remove-if
- remove-if-not
- replace
- reverse
- search
- some
- sort
- stable-sort
- subseq
- substitute
- substitute-if
- substitute-if-not

5.3 Hash Tables

5.4 Trees

5.5 Association Lists

5.6 Property Lists

5.7 Records

5.8 Structures

5.9 Classes

6 Creating Variables

7 Functions

currying / partial no side effects let / flet

8 Example 2

8.1 TODO Decide on an example that uses the above.

9 Declare, declaim, proclaim

10 Control Operations

11 Error Handling

12 Lazyiness

13 Streams

14 Macro Dispatching Characters

set-macro-character symbol macros

15 Macros

16 Multimethods

17 CLOS

18 Packages

19 Standard Libraries

20 Important Libraries

21 Working with GNU Emacs and Slime