Common Lisp Essentials for Scheme programmers

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with many thanks to Dr. Pascal Costanza
Agenda

Language culture
1. History
2. Philosophy
3. Community

Language abstractions
4. Lisp-1 vs. Lisp-2
5. Lambda lists
6. Packages
7. Gen. assignment
8. Type system

Language extensions
9. Object system

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History
Basic Misconceptions

- Scheme is a cleaned-up version of all Lisps.
  - Common Lisp is the newer dialect!
  - *The Evolution of Lisp* (Steele and Gabriel)
    www.dreamsongs.com/Essays.html

- Common Lisp is slow.
  - Advanced, mature compilers.

- Common Lisp is not standard.
  - ANSI standard (first ever for an OOPL!)

- Common Lisp is dead.
  - Web applications, games, home appliances, and many more.
History

- **1956**: McCarthy’s LIS Processing language, for symbolic data processing.
- **1975**: “Scheme – An Interpreter for Extended Lambda Calculus” (Sussman, Steele)
- **1976-1980**: ‘Lambda Papers’ (Sussman, Steele)

No amount of language design can force a programmer to write clear programs. [...] The emphasis should not be on eliminating ‘bad’ language constructs, but on discovering or inventing helpful ones.
History

- **1982**: “An Overview of Common LISP” (Steele et al.)
- **1984**: “Common Lisp the Language” (Steele et al.)
CL’s First Goals

- Commonality among Lisp dialects
- Portability for “a broad class of machines”
- Consistency across interpreter & compilers
- Expressiveness based on experience
- Compatibility with previous Lisp dialects
- Efficiency: possibility to build optimizing compilers
- Stability: only “slow” changes to the language
CL’s First Non-Goals

- Graphics
- Multiprocessing
- Object-oriented programming
History

- 1989: “Common Lisp the Language, 2nd Edition” (Steele et al.)

There are now many implementations of Common Lisp [...]. What is more, all the goals [...] have been achieved, most notably that of portability. Moving large bodies of Lisp code from one computer to another is now routine.
Further History

- Lisp Machines (80s)
- IEEE Scheme (1990)
- ANSI Common Lisp (1996)
  - 1100 pages describing 1000 funcs and vars
- ISO ISLISP (1997, mostly a CL subset)
- R5RS (1998, macros now officially supported)
- R6RS (2007)
Philosophy
> Scheme Philosophy

- Focus on *simplicity* and *homogeneity*.

  ➡ Occam’s Razor
  
  *when there are two explanations for the same phenomenon, then the explanation which uses the smallest number of assumptions and concepts must be the right one*

- Single paradigm.
  - “everything is a lambda expression”

- Advocates functional programming
  - side effects should be marked with a bang (!)
CL Philosophy

- Focus on *expressiveness*, *pragmatics* and *efficiency*.
- CL integrates the OOP, FP and IP paradigms.
- IP: assignment, iteration, go.
- FP: lexical closures, first-class functions.
- IP & FP: many functions come both with and without side effects.
  - cons & push
  - adjoin & pushnew
  - remove & delete
  - reverse & nreverse
  - etc.
Abstractions

Pragmatics
1. Truth and falsity
2. Evaluation order
3. Lisp-1 vs. Lisp-2
4. Lambda lists
5. Generalised assignment

Control flow
6. Loop
7. Throw / catch
8. Conditions

Efficiency & correctness
9. Type system

Large scale
10. Dynamic scoping
11. Packages
12. CLOS

Meta & extensibility
13. Macros
14. MOP
Truth and Falsehood

• Scheme
  - #t and every non-#f value vs. #f
  - predicates end in “?”

• Common Lisp
  - t and every non-nil value vs. nil
  - predicates usually end in “p” or “-p”
  - notable exceptions: eq, eql, equal
Truth and Falsehood

- **CL:**
  \[(cdr (assoc key alist))\]

- **Scheme:**
  \[(let ((val (assq key a-list)))
    (cond ((not (null? val)) (cdr val))
          (else nil)))\]

- **Ballad Dedicated to the Growth of Programs**
  (Google for it)
Evaluation Orders

• In Scheme, (+ i j k) may be evaluated in any order
  • this is specified
  • so never say: (+ i (set! i (+ i 1)))

• In CL, things are evaluated left to right.
  • specified in all useful cases
  • so (+ i (setf i (+ i 1))) is well defined.
Iteration vs. Recursion

- Scheme: proper tail recursion.
- CL: no requirements, but usually optional tail recursion elimination.
  
  (proclaim '(optimize speed))

- Scheme: do, named let
- CL: do, do*, dolist, dotimes, loop
Special Variables

• In CL, all global variables are dynamically scoped ("special variables").

• (Note: not the functions!)

• Dynamic scope: global scope + dynamic extent.

• By convention, names are marked with *

  ➔ *package* *features* *print-base*
Symbols

- **Symbolic computation** is the kind of programming that relies on a symbol data type.
- Symbols are central to all Lisp dialects.
- Common Lisp has advanced facilities to work with symbols.
Packages

- Packages are containers for symbols, used as namespaces or “shared vocabularies”.
- Packages help avoiding name pollution and clashes.
- The CL reader uses packages to translate the literal names it finds into symbols.
  
  (find-symbol "CAR" "CL") → 'car
  (find-symbol "CAr" "CL") → nil

- Symbols can be internal, external or inherited.
- So we don’t export functions etc., but symbols.
Symbol Literals

- **Unqualified (current package)**
  - foo, Foo, FoO, FOO

- **Qualified**
  - *External* – acme:foo
  - *Internal* – acme::foo
  - *Keywords* – :foo keyword:foo
    - (eq ':foo :foo) → T
  - *Uninterned* – #:foo
    - (eq '#:foo #:foo) → NIL
Packages: How it Works

- (in-package "BANK")
  (export 'withdraw)
  (defun withdraw (x) ...)

- Allows other packages to say:
  (bank:withdraw 500)

- Or:
  (use-package "BANK")
  (withdraw 500)
Packages: Utilities

(defpackage bank
 (:documentation "Sample package")
 (:use common-lisp)
 (:export withdraw deposit consult ...))
Lisp-1 vs. Lisp-2

• In Scheme, a symbol may be bound to a value, and functions in particular are values.

• In CL, functions and values have different namespaces. In a form,

- car position is interpreted in function space
- cdr positions are interpreted in value space

• So you can say (flet ((fun (x) (1+ x)))
  (let ((fun 42))
      (fun fun)))
Lisp-1 vs. Lisp-2

- There are accessors for each namespace:
  - (symbol-function 'fun) or #'fun or (function fun)
  - (symbol-value 'fun) or fun

- Call functional values as:
  (fun 42) or (funcall #'fun 42) or (apply #'fun (list 42))

*Functions are first-class just like in Scheme*
Why Lisp-1?

• Homogeneity: let all positions in a form be evaluated the same. You can say (((f x) y) z)

• Avoid having separate binding manipulation constructs for each namespace.

- CL:
  let / flet
  boundp / fboundp
  symbol-value / symbol-function
  defun / defvar
But why Lisp-2?

• In practice, having the possibility of reusing names for functions and variables is very handy.
  - No need to prepend ‘get-’ to getters

  (let ((age (age person)))
    (+ age 10))

• Lisp-2 is practical. About 80% of CL programmers use it.
• CL's parameter lists provide a convenient solution to several common coding problems.
Lists: Optional Args

- CL: (defun foo (a b &optional (c 0) d)
  (list a b c d))

(foo 1 2) ➞ (1 2 0 NIL)
(foo 1 2 3) ➞ (1 2 3 NIL)
(foo 1 2 3 4) ➞ (1 2 3 4)
• Scheme:
  (define (format ctrl-string . objects) ...)
  (define (+ . numbers) ...)

• CL:
  (defun format (stream string &rest values) ...) 
  (defun + (&rest numbers) ...)
> A Lists: Keyword Args

(defun find (item list &key (test #'eql) (key #'identity)) ...)

(find "Karl" *list-of-persons*
  :key #'person-name
  :test #'string=)
(defun withdraw (...) ...)

(...)

(flet ((withdraw (&rest args &key amount &allow-other-keys))

(if (> amount 100000)

(apply #'withdraw :amount 100000 args)

(apply #'withdraw args))))

(...)

(...)
Lambda Lists

- &rest, &body: rest parameters
- &optional: optional parameters
- &key, &allow-other-keys: keyword parameters
- &environment: lexical environment
- &aux: local variables
- &whole: the whole form
Generalised Assignment

• ...or “generalized references”

• like “:=” or “=” in Algol-style languages, with arbitrary left-hand sides

• (setf (some-form ...) (some-value ...))

• predefined acceptable forms for left-hand sides
+ framework for user-defined forms

<table>
<thead>
<tr>
<th>Python</th>
<th>CL</th>
</tr>
</thead>
<tbody>
<tr>
<td>x = 10</td>
<td>(setf x 10)</td>
</tr>
<tr>
<td>a[0] = 10</td>
<td>(setf (aref a 0) 10)</td>
</tr>
<tr>
<td>hash['key'] = 10</td>
<td>(setf (gethash 'key hash) 10)</td>
</tr>
<tr>
<td>o.field = 10</td>
<td>(setf (field o) 10)</td>
</tr>
</tbody>
</table>
Generalised Assignment

• Earlier dialects of Lisp would often have pairs of functions for reading and writing data.

• The `setf` macro improves CL’s orthogonality.

• In CL there are only “getters”, and setters come for free.

• `(age person) ➞ 32`

• `(setf (age person) 42) ➞ 42`
Assignment Functions

- (defun make-cell (value) (vector value))
  (defun cell-value (cell) (svref cell 0))
  (defun (setf cell-value) (value cell)
    (setf (svref cell 0) value))
- (setf (cell-value some-cell) 42)
- macros also supported
Type System

- A type is a possibly infinite set of objects.

- CL allows optional declaration of types.
  (declare (type integer *my-counter*))
  (declare (integer x y z))
  (the integer (* x y))

- Usually, CL implementations take type declarations as a promise for code optimization.

- Creation of new types: deftype, defstruct, defclass, define-condition.
Type System

Type queries

- (type-of 1) ➞ 'bit
- (type-of 2) ➞ '(integer 0 536870911)
- (type-of "hola") ➞ (simple-array character (4))
- (typep 3 '(integer 0 2)) ➞ nil
- (typep 'a '(and symbol (not null))) ➞ t
- (subtypep 'integer 'number) ➞ t
Finally

- CL defines a large number of predefined data structures and operations:
  
  CLOS, structures, conditions, numerical tower, extensible characters, optionally typed arrays, multidimensional arrays, hash tables, filenames, streams, printer, reader.

- Apart from these differences, Scheme and Common Lisp are almost the same. ;)

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CLOS
the common lisp object system
class OutputStream {
    void println(Object obj) {
        ...
    }
    ...
}
out.println(pascal);
...in Lisp syntax...

```
out.println(pascal);
```

(send out 'println pascal)
> ...the receiver is just another argument...

(call receiver message args ...)

(call message receiver args ...)

(call message all-args ...)

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> ...“call” is redundant...

(call message args ...)

(message args ...)

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...so now we have generic functions!

out.println(pascal);

(println out pascal)
Classes

(defclass person (standard-object)
  ((name :accessor person-name
     :initarg :name)
   (address :accessor person-address
     :initarg :address))
  (:documentation "Basic person."))
Classes and Superclasses

(defclass person (standard-object)
  ((name :accessor person-name
         :initarg :name)
   (address :accessor person-address
            :initarg :address))
  (:documentation "Basic person."))
(defclass person (standard-object)
   ((name :accessor person-name
       :initarg :name)
    (address :accessor person-address
       :initarg :address))
 (:documentation "Basic person.")
(defclass person (standard-object)
  ((name :accessor person-name
         :initarg :name)
   (address :accessor person-address
            :initarg :address))
  (:documentation "Basic person.
))
(defclass person (standard-object)
  ((name :accessor person-name :initarg :name)
   (address :accessor person-address :initarg :address))
  (:documentation "Basic person."))

(defparameter *dilbert*
  (make-instance 'person :name "Dilbert" :address "Brussels"))

(person-name *dilbert*) → "Dilbert"
Generic Functions

- Invented when Lispers implemented OOP.
- Generic functions were already needed. Mathematical operations are generic! They work on ints, floats, complex, etc.

```
(defun generic + (x y)
  :documentation "returns the sum of x and y")
(defmethod + ((x int) (y int)) ...)
(defmethod + ((x float) (y float)) ...)
(defmethod + ((x complex) (y complex)) ...)
```
Generic Functions

- Methods belong to the generic function.
- The GF is responsible for determining what method(s) to run in response to a particular invocation.

➡ Multiple dispatch: consider all the arguments when selecting applicable and most specific methods.

➡ Advice: add qualified methods that are called before, after or around everything else.
Inheritance

• `(defgeneric display (object))`

• `(defmethod display ((object person))
  (print (person-name object))
  (print (person-address object)))`

• `(defclass employee (person)
   ((employer :accessor person-employer
               :initarg :employer)))`

• `(defmethod display ((object employee))
   (call-next-method)
   (display (person-employer object)))`
GFs & Methods

• (defmethod display ((object person))
  ...)

• (defmethod display :before ((object person))
  ...)

• Standard method combination allows for primary, :before, :after and :around methods.
• (defgeneric display (object)
   (:method-combination progn :most-specific-last))

• (defmethod display progn ((object person))
   (print (person-name object))
   (print (person-address object)))

• (defmethod display progn ((object employee))
   (print (person-employer object)))
Now consider:

```java
public class Person {
    public boolean equals(Person other) {
        this.name().equals(other.name());
    }
}
```

Now consider:

```java
public class Object {
    public boolean equals(Object other) {
        return this == other;
    }
}
```

```java
public class Person {
    public boolean equals(Person other) {
        return this.name().equals(other.name());
    }
}
```

Object a = new Person("juan");
Object b = new Person("juan");
a.equals(b)
Now consider:

```java
public class Person {
    public boolean equals(Person other) {
        return this.name().equals(other.name());
    }
}
```

Now consider:

```java
Object a = new Person("juan");
Object b = new Person("juan");
a.equals(b) → false
```
Single Dispatch

```java
public class Object {
    public boolean equals(Object other) {
        return this == other;
    }
}

public class Person {
    public boolean equals(Object other) {
        return this.name().equals(other.name());
    }
}
```

Now consider:

```java
Object a = new Person("juan");
Object b = new Person("juan");
a.equals(b) -> false
```
Now consider:

```
Object a = new Person("juan");
Object b = new Person("juan");
a.equals(b)  \rightarrow false
```

dynamic method binding based on receiver only
What happens when you run the following main method?

```java
public class Main {
    public static void main(String[] argv) {
        A obj = argv[0].equals("A") ? new A() : new B();
        obj.foo(obj);
    }
}
```
What happens when you run the following main method?

```java
public class Main {
    public static void main(String[] argv) {
        A obj = argv[0].equals("A") ? new A() : new B();
        obj.foo(obj);
    }
}
```

```
bash$ java Main A
```

> Single Dispatch

```java
public class A {
    public void foo(A a) { System.out.println("A/A"); }
    public void foo(B b) { System.out.println("A/B"); }
}

public class B extends A {
    public void foo(A a) { System.out.println("B/A"); }
    public void foo(B b) { System.out.println("B/B"); }
}
```
What happens when you run the following main method?

```java
public class Main {
    public static void main(String[] argv) {
        A obj = argv[0].equals("A") ? new A() : new B();
        obj.foo(obj);
    }
}
```

bash$ java Main A

“A/A”
What happens when you run the following main method?

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public class Main {
    public static void main(String[] argv) {
        A obj = argv[0].equals("A") ? new A() : new B();
        obj.foo(obj);
    }
}
```

bash$ java Main A
bash$ java Main B

“A/A”
public class A {
  public void foo(A a) { System.out.println("A/A"); }
  public void foo(B b) { System.out.println("A/B"); }
}

public class B extends A {
  public void foo(A a) { System.out.println("B/A"); }
  public void foo(B b) { System.out.println("B/B"); }
}

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bash$ java Main A
"A/A"
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"B/A"
public class A {
    public void foo(A a) { System.out.println("A/A"); }
    public void foo(B b) { System.out.println("A/B"); }
}

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What happens when you run the following main method?

public class Main {
    public static void main(String[] argv) {
        A obj = argv[0].equals("A") ? new A() : new B();
        obj.foo(obj);
    }
}

bash$ java Main A
"A/A"
bash$ java Main B
"B/A" "B/B"
Multiple Dispatch

(defclass A () ())
(defclass B (A) ())

(defmethod foo ((x A) (y A)) (print "A/A"))
(defmethod foo ((x A) (y B)) (print "A/B"))
(defmethod foo ((x B) (y A)) (print "B/A"))
(defmethod foo ((x B) (y B)) (print "B/B"))

If you try:

(defun test (class)
  (let ((obj (make-instance class)))
    (foo obj obj)))
Multiple Dispatch

(defclass A () ())
(defclass B (A) ())

(defmethod foo ((x A) (y A)) (print "A/A"))
(defmethod foo ((x A) (y B)) (print "A/B"))

(defmethod foo ((x B) (y A)) (print "B/A"))
(defmethod foo ((x B) (y B)) (print "B/B"))

If you try:

(defun test (class)
   (let ((obj (make-instance class)))
      (foo obj obj)))

(test 'a)
(defclass A () ())
(defclass B (A) ())

(defmethod foo ((x A) (y A)) (print "A/A"))
(defmethod foo ((x A) (y B)) (print "A/B"))
(defmethod foo ((x B) (y A)) (print "B/A"))
(defmethod foo ((x B) (y B)) (print "B/B"))

If you try:

(defun test (class)
  (let ((obj (make-instance class)))
    (foo obj obj)))

(test 'a)  "A/A"
Multiple Dispatch

(defun test (class)
   (let ((obj (make-instance class)))
      (foo obj obj)))

If you try:

(test 'a)
(test 'b)
Multiple Dispatch

(defun test (class)
   (let ((obj (make-instance class)))
      (foo obj obj)))

(test 'a)  "A/A"
(test 'b)  "B/B"
Concluding Remarks
Greenspun’s Tenth Rule

“Any sufficiently complicated C or Fortran program contains an ad-hoc, informally-specified bug-ridden slow implementation of half of Common Lisp.”
Important Literature

• Peter Norvig, Paradigms of Artificial Intelligence Programming (PAIP)
  - CL’s SICP

• Paul Graham, On Lisp - the book about macros
  (out of print, but see www.paulgraham.com)

• Peter Seibel, Practical Common Lisp, 2005,
  www.gigamonkeys.com/book
Important Literature

- Guy Steele, Common Lisp The Language, 2nd Edition (CLtL2 - pre-ANSI!)
- HyperSpec, (ANSI standard), Google for it!
- Pascal’s highly opinionated guide [http://p-cos.net/lisp/guide.html](http://p-cos.net/lisp/guide.html)
- ISLISP: [www.islisp.info](http://www.islisp.info)