Robot Programming with Lisp

2. Imperative Programming

Arthur Niedzwiecki

Institute for Artificial Intelligence
University of Bremen

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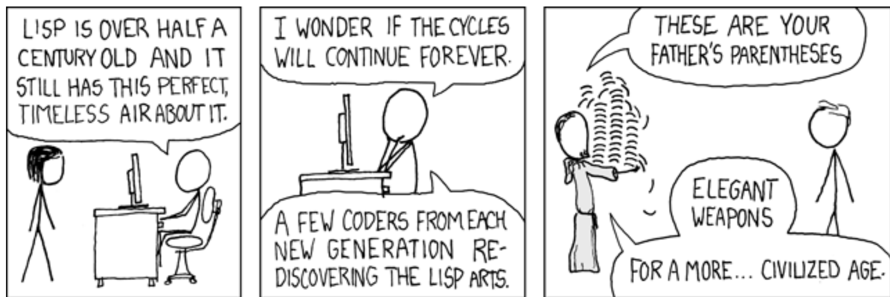
Lisp the Language

LISP $\leftrightarrow$ LISt Processing language

Lisp the Language

LISP $\leftrightarrow$ LISt Processing language

(LISP $\leftrightarrow$ Lots of Irritating Superfluous Parenthesis)



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- *Anonymous functions*
- *Side-effects* are allowed, not purely functional as, e.g., Haskell
- *Run-time code generation*
- *Easily-expandable* through the powerful macros mechanism

Short History

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- 2007: Clojure

Hello World

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Java "Hello World"

```
public class HelloWorld {
  public static void main(String[ ] args) {
    System.out.println("Hello World!");
  }
}
```

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```

Lisp “Hello World”

```
"Hello World!"
```

Hello World

Java "Hello World"

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}
```

Lisp "Hello World"

```lisp
"Hello World!"
```

- Rapid prototyping
- Read-Eval-Print Loop (Lisp shell)

Polish Notation

Also known as **prefix notation**.

Examples

```
(+ 1 2 3 4)

(sin 3.14)

(/ (+ 4 2) 3)

(list 1 2 3)

(defun return-my-arg (arg)
  arg)

(return-my-arg 302)
```

S-expressions (S for symbolic)

Numbers

Integer

```
CL-USER> (describe 1)
1
  [fixnum]
```

Float

```
CL-USER> (describe 1.0)
         (describe 1f0)
1.0
  [single-float]
CL-USER> 1f3
1000.0
```

Double

```
CL-USER> (describe 1d0)
1.0d0
  [double-float]
```

More Numbers

Ratio

```
CL-USER> (/ 1 3)
1/3
CL-USER> (describe 1/3)
1/3
  [ratio]

CL-USER> (describe (/ 1.0 3))
0.33333334
  [single-float]
```

Numeral Systems

```
CL-USER> #xFF
255

CL-USER> #b1111
15
```

Chars and Strings

Char

```
CL-USER> (describe #\Z)
#\Z
  [standard-char]
:_Char-code: 90
:_Char-name: LATIN_CAPITAL_LETTER_Z

CL-USER> (describe #\Ö)
#\LATIN_CAPITAL_LETTER_O_WITH_DIAERESIS
  [character]
:_Char-code: 214
:_Char-name: LATIN_CAPITAL_LETTER_O_WITH_DIAERESIS
```

String

```
CL-USER> (describe "hello")
"hello"
  [simple-string]
```

Variables and Symbols

Variable

```
CL-USER> x
```

```
The variable X is unbound.
```

Symbol

```
CL-USER> (describe 'x)
COMMON-LISP-USER::X
  [symbol]
```

Keyword

```
CL-USER> (describe :x)
         (describe ':x)
:X
  [symbol]
X names a constant variable:
  Value: :X
```

Booleans

False

```
CL-USER> (describe NIL)
COMMON-LISP:NIL
  [null]
NIL names a constant variable:
  Value: NIL
NIL names a primitive type-specifier
```

True

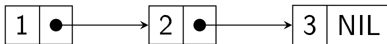
```
CL-USER> (describe T)
COMMON-LISP:T
  [symbol]
T names a constant variable:
  Value: T
T names the built-in-class #<BUILT-IN-CLASS T>:
  ...
T names a primitive type-specifier
```

Lists

List

```
CL-USER> (list 1 2 3)
(1 2 3)

CL-USER> *
(1 2 3)

CL-USER> (describe *)
(1 2 3)
  [list]

CL-USER> '(1 2 3)
(1 2 3)

CL-USER> '((1.1 1.2) (2.1 2.2) (some more stuff) (+ 1 3))
((1.1 1.2) (2.1 2.2) (SOME MORE STUFF) (+ 1 3))
```

Lists Explained

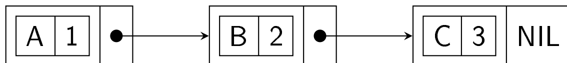


It's a linked list where each element has only 2 slots: `value` and `next-elem`. `next-elem` of the last element is `NIL`.
The elements are called *cons cells* or *cons pairs*.

List and NIL

```
CL-USER> '()
NIL
CL-USER> (list )
NIL
CL-USER> (type-of '(1 1 1))
CONS
CL-USER> (listp '(1 1 1))
T
CL-USER> (listp '())
T
```

Association Lists



It's a list where the first element of each cons cell is itself a cons cell.

AList

```
CL-USER> '((A . 1) (B . 2) (C . 3))
((A . 1) (B . 2) (C . 3))

CL-USER> (describe *)
((A . 1) (B . 2) (C . 3))
  [list]
```

Arrays

Vector

```
CL-USER> #(1 2 3)
#(1 2 3)
```

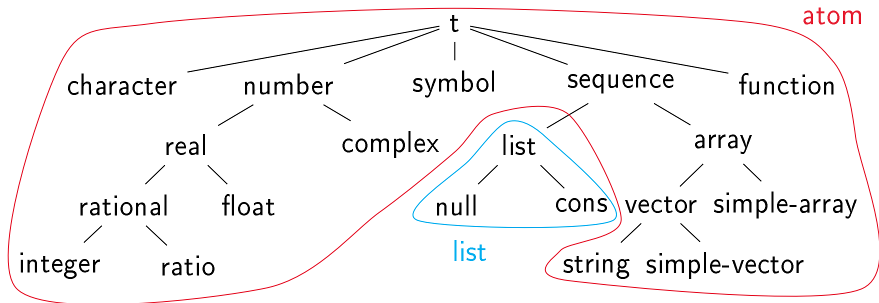
Matrix

```
CL-USER> #2A((1 2) (3 4))
#2A((1 2) (3 4))
```

Mutli-dimensional array

```
CL-USER> (make-array '(4 2 3)
            :initial-contents
            '(((a b c) (1 2 3))
              ((d e f) (3 1 2))
              ((g h i) (2 3 1))
              ((j k l) (0 0 0))))
#3A(((A B C) (1 2 3)) ((D E F) (3 1 2)) ((G H I) (2 3 1)) ((J K L)
(0 0 0)))
```

Data Types



The diagram is very simplified.

Also, the following is completely omitted:

- `standard-object` (CLOS)
- `stream` (files)
- `condition` (error handling), ...

Data and Code

Quoted constructs (both atoms and lists) are *data*:

```
CL-USER> '"abc"
"abc"

CL-USER> '(+ 1 2)
(+ 1 2)
```

Everything else is *code*:

```
CL-USER> (+ 1 2)
3
```

Conclusion: run-time code generation and manipulation done easily!

```
CL-USER> (eval '(+ 1 2)) ; but don't EVER use "eval" directly
3
```

Code as Composition of Lists

Code is one big nested list. Depending on the first element, an S-expression is compiled into a function, special form or macro.

Function

```
CL-USER> '(list '+ 1 2)
(LIST '+ 1 2)
CL-USER> (eval *)
(+ 1 2)
CL-USER> (eval *)
3
```

Special Form

```
CL-USER> (list 'if t 1 2)
(IF T
    1
    2)
CL-USER> (eval *)
1
```

Macro

```
CL-USER> (list 'defun 'return-a '(a) 'a)
(DEFUN RETURN-A (A) A)
CL-USER> (eval *)
RETURN-A
CL-USER> (return-a 5)
5
```

More on Symbols

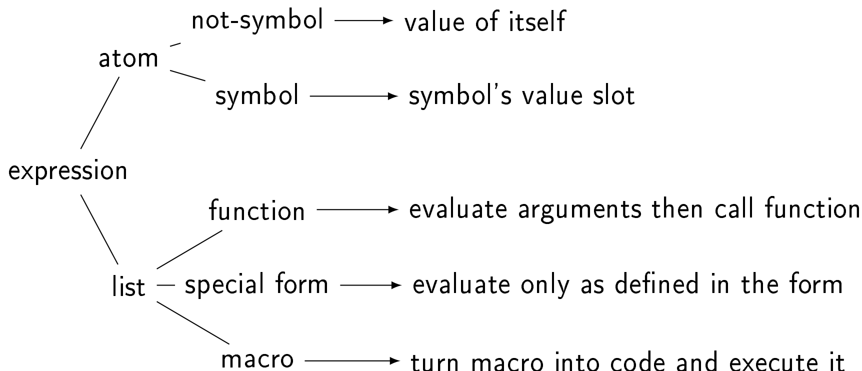
Symbol

```
CL-USER> (setf my-symbol 1)
1
CL-USER> (defun my-symbol () 2)
MY-SYMBOL
CL-USER> (setf (get 'my-symbol 'my-property) 3)
3
CL-USER> 'my-symbol
MY-SYMBOL
```

Symbol	
Field	**Value**
Name	`my-symbol`
Package	`COMMON-LISP-USER` aka `CL-USER`
Value	`1`
Function	`#<FUNCTION MY-SYMBOL>`
Property list	`(MY-PROPERTY 3)`

To inspect an expression in the REPL:
right click → `inspect`.

Read-Eval-Print Loop



An example for special form REPLoop evaluation is the `if` command:
it evaluates only the first parameter, then chooses to evaluate either the second or third.

Imperative Programming

The *imperative programming* paradigm represents programs as **sequences of commands**.

One important property thereof is that the program has a **state** and the commands manipulate it to achieve a desired state.

Common Lisp has powerful means for imperative programming (e.g., very advanced looping mechanisms) but many traditionally imperative constructs are implemented differently in Lisp.

We'll consider both ways (*imperative vs. functional*) and then compare them.

Special Variables

Global Variables

```
CL-USER> (defvar *my-global-var* 'some-value "test variable")
*MY-GLOBAL-VAR*
CL-USER> *my-global-var*
SOME-VALUE
CL-USER> (setf *my-global-var* 23)
23
CL-USER> *my-global-var*
23
CL-USER> (incf *my-global-var*)
24
CL-USER> (defvar *my-global-var* 25)
*MY-GLOBAL-VAR*
CL-USER> *my-global-var*
24
```

Naming convention: `*the-variable-name*`.

Special Variables [2]

Parameters

```
CL-USER> (defparameter *my-param* 0.01)
*MY-PARAM*
CL-USER> *my-param*
0.01
CL-USER> (setf *my-param* 0.1)
0.1
CL-USER> *my-param*
0.1
CL-USER> (defparameter *another-param*)
error while parsing arguments to DEFMACRO DEFPARAMETER
CL-USER> (defparameter *my-param* 0.5)
*MY-PARAM*
CL-USER> *my-param*
0.5
```

Special Variables [3]

Constants

```
CL-USER> (defconstant +my-pi+ 3.14)
+MY-PI+
CL-USER> +my-pi+
3.14
CL-USER> (setf +my-pi+ 3.14159)
Condition: +MY-PI+ is a constant and thus can't be set.
CL-USER> (defconstant +my-pi+ 3.14159)
+MY-PI+
Condition: The constant +MY-PI+ is being redefined.
```

Naming convention: `+the-constant-name+`.

Local Variables

Defining Local Variables

```
CL-USER> (let ((a 1)
               (b 2))
          (print a)
          b)
1
2
CL-USER> (print b)
The variable B is unbound.
```

Dependent Local Variables

```
CL-USER> (let* ((a 1)
                (b (+ a 2)))
          (print a)
          b)
1
3
```

Type Operations

Predicates

```
(type-of 5) ⇒ INTEGER
(typep 5 'number) ⇒ T
(type-of #c(5 1)) ⇒ COMPLEX
(type-of 'nil) ⇒ NULL
(listp '(1 2 3)) ⇒ T
(symbolp 'a) ⇒ T
(type-of :k) ⇒ KEYWORD
(symbolp :k) ⇒ T
```

Casts

```
(coerce '(a b c) 'vector) ⇒ #(A B C)
(coerce "a" 'character) ⇒ #\a
(coerce 7/2 'float) ⇒ 3.5
(coerce 7/2 'number) ⇒ 7/2
(coerce 7/2 't) ⇒ 7/2
(coerce 7/2 'null) ⇒ 7/2 can't be converted to type NULL.
```

Comparing

Casts

```
CL-USER> (> 2 1.5d0)
T
CL-USER> (<= 3.0d0 3)
T
CL-USER> (eq 1 1)
T
CL-USER> (eq 'bla 'bla)
T
CL-USER> (eq "bla" "bla")
NIL
CL-USER> (eq '(1 2 3) '(1 2 3))
NIL
CL-USER> (eql '(1 2 3) '(1 2 3))
NIL
CL-USER> (eql 1.0 1)
NIL
```

```
CL-USER> (equal '(1 2 3) '(1 2 3))
T
CL-USER> (equal "bla" "bla")
T
CL-USER> (equal "bla" "Bla")
NIL
CL-USER> (equalp "bla" "Bla")
T
CL-USER> (equal #(1 2 3) #(1 2 3))
NIL
CL-USER> (equalp #(1 2 3) #(1 2 3))
T
CL-USER> (= 2.4 2.4d0)
NIL
CL-USER> (string= "hello" "hello")
T
```

Comparing [2]

x	y	eq	eql	equal	equalp
'a	'a	T	T	T	T
0	0	?	T	T	T
'(a)	'(a)	nil	nil	T	T
"ab"	"ab"	nil	nil	T	T
"Ab"	"aB"	nil	nil	nil	T
0	0.0	nil	nil	nil	T
0	1	nil	nil	nil	nil

= is for comparing numbers of the same type.

`string=` is an advanced tool for comparing strings.

List Operations

Lists

```
CL-USER> (cons 1 (cons 2 (cons 3 nil)))
CL-USER> (list 1 2 3)
CL-USER> '(1 2 3)
(1 2 3)

CL-USER> (listp *)
T
CL-USER> (null **)
NIL
CL-USER> (null '())
T
CL-USER> (null '(()))
NIL
CL-USER> (member 2 '(1 2 3))
(2 3)
CL-USER> (member 2 '((1 2) (3 4)))
NIL
```

```
CL-USER> (defvar *my-list*
                 '(1 2 3 4 5))
*MY-LIST*
CL-USER> (first *my-list*)
1
CL-USER> (rest *my-list*)
(2 3 4 5)
CL-USER> (nth 4 *my-list*)
5
CL-USER> (fourth *my-list*)
4
CL-USER> (last *my-list*)
(5)

CL-USER> (push 0 *my-list*)
(0 1 2 3 4 5)
```

AList Operations

Association Lists

```
CL-USER> (cons (cons "Alice" "Jones")
               (cons (cons "Bill" "Smith")
                     (cons (cons "Cathy" "Smith")
                           nil)))
(("Alice" . "Jones") ("Bill" . "Smith") ("Cathy" . "Smith"))
CL-USER> '(("Alice" . "Jones") ("Bill" . "Smith") ("Cathy" . "Smith"))
(("Alice" . "Jones") ("Bill" . "Smith") ("Cathy" . "Smith"))
CL-USER> (assoc "Alice" *)
NIL
CL-USER> (assoc "Alice" ** :test \#'string=)
("Alice" . "Jones")
CL-USER> (rassoc "Smith" *** :test \#'string=)
("Bill" . "Smith")
```

Property Lists and Vectors

Property Lists

```
CL-USER> (defvar *plist* '())
*PLIST*
CL-USER> (setf (getf *plist* 'key) 'value)
VALUE
CL-USER> *plist*
(KEY VALUE)
CL-USER> (setf (getf *plist* 'another-key)
               'another-value)
ANOTHER-VALUE
CL-USER> *plist*
(ANOTHER-KEY ANOTHER-VALUE KEY VALUE)
CL-USER> (setf (getf *plist* 'key)
               'new-value)
NEW-VALUE
CL-USER> *plist*
(ANOTHER-KEY ANOTHER-VALUE KEY NEW-VALUE)
```

Vectors

```
CL-USER> #2A((1 2) (3 4))
#2A((1 2) (3 4))
CL-USER> (aref * 0 0)
1
CL-USER> (aref ** 1 1)
4
CL-USER> #(1 2 3 4 5 6)
#(1 2 3 4 5 6)
CL-USER> (setf (aref * 5) 9)
9
CL-USER> **
#(1 2 3 4 5 9)
```

Format Statements, Streams and Files

```
CL-USER> (read)
hello world
HELLO
CL-USER> (read-line)
hello world
"hello world"
CL-USER> (format nil "symbol to ~a" 'string)
"symbol to STRING"
CL-USER> (format t "1 + 1 = ~a~%" (+ 1 1))
1 + 1 = 2
NIL
CL-USER>
(with-open-file (stream "~/.bashrc")
    (do ((line (read-line stream nil)
               (read-line stream nil)))
        ((null line))
      (print line)))
```

Program Flow Constructs

if, case, unless

```
CL-USER> (defvar *weather* 'rainy)
*WEATHER*
CL-USER> (if (eql *weather* 'rainy)
             (format t "I'm staying at home.")
             (format t "Let's go for a walk!"))
I'm staying at home.
NIL
CL-USER> (case *weather*
           (rainy "Stay home")
           (snowing "Go ski")
           (sunny "Got to the park")
           (otherwise "Hmmm..."))
"Stay home"
CL-USER> (setf *weather* 'very-nice)
VERY-NICE
CL-USER> (unless (eql *weather* 'rainy)
           (format t "Let's go for a walk!"))
Let's go for a walk!
```

Program Flow Constructs [2]

when, progn

```
CL-USER> (setf *weather* 'rainy)
RAINY
CL-USER> (if (eql *weather* 'rainy)
             (progn
               (format t "Let's go for a walk.~%")
               (format t "But don't forget your umbrella.~%")))
Let's go for a walk.
But don't forget your umbrella.
NIL
CL-USER> (when (eql *weather* 'rainy)
           (format t "Let's go for a walk.~%")
           (format t "But don't forget your umbrella.~%"))
Let's go for a walk.
But don't forget your umbrella.
NIL
```

Program Flow Constructs [3]

prog1, cond

```
CL-USER> (progn (setf *weather* 'it-rains-cats)
                (format t "The weather today is ~a~%" *weather*))
The weather today is IT-RAINS-CATS
NIL
CL-USER> (prog1 (setf *weather* 'whatever)
                (format t "The weather today is ~a~%" *weather*))
The weather today is WHATEVER
WHATEVER

CL-USER> (defvar *x* 1.5)
*X*
CL-USER> (cond ((< *x* 0) -*x*)
               ((< *x* 1) 1)
               (t *x*))
1.5
```

Logical Operators

and, or, not

```
CL-USER> (defparameter *threshold* 0.001)
*THRESHOLD*
CL-USER> (if (not (and (<= *threshold* 1) (> *threshold* 0)))
             (error "*threshold* should lie within (0; 1]~%"))
NIL
CL-USER> (if (or (> *threshold* 1) (<= *threshold* 0))
             (error "*threshold* should lie within (0; 1]~%"))
NIL
CL-USER> (unless (and (<= *threshold* 1) (> *threshold* 0))
           (error "*threshold* should lie within (0; 1]~%"))
NIL
```

Looping

dotimes, dolist, loop

```
CL-USER> (dotimes (i 10 (format t "the end~%"))
           (format t "~d " i))
0 1 2 3 4 5 6 7 8 9 the end
NIL
CL-USER> (defparameter *random* (loop repeat 10 collect (random 10000)))
*RANDOM*
CL-USER> (dolist (element *random* (format t "...~%"))
           (format t "~a " element))
6505 5293 2987 2440 8012 3258 9871 896 2501 5158 ...
NIL
CL-USER> (loop for i in *random*
               counting (evenp i) into evens
               counting (oddp i) into odds
               summing i into total
               maximizing i into max
               minimizing i into min
               finally (return (list evens odds total max min)))
(5 5 46921 9871 896)
```

Defining a Function and Calling It

Defining a Function

```
CL-USER>
(defun my-cool-function-name (arg-1 arg-2 arg-3 arg-4)
  "This function combines its 4 input arguments into a list
and returns it."
  (list arg-1 arg-2 arg-3 arg-4))
MY-COOL-FUNCTION-NAME
```

Calling a Function

```
CL-USER> (my-cool-function-name 1 3 5 7)
(1 3 5 7)
```

Documentation

Slime hotkeys (in the REPL or `.lisp` file):

`C-c C-d d`	describe symbol at point
`C-c C-d f`	describe function at point
`C-c C-d h`	open Hyperspec definition
`C-c C-d C-h`	list all Slime bindings for getting documentation
`M-.`	go into function definition
`M-,`	return one level up from the definition stack
`C-c M-m`	macroexpand expression at point
`C-c C-v i`	inspect presentation at point (only in REPL) (or *right click* → `inspect`)

Hint: cursor is called "*point*" in Emacs.

Assignment goals

Lisp basics

Task 1: Update your repository

- Go to your `lisp_course_material` directory and update it:

```
$ roscd && cd ../src/lisp_course_exercises
$ git pull origin master
```

- You will see new directories that appeared there (`assignment_2`, `cram`):

```
$ ll
```

- Install dependencies for CRAM:

```
$ cd ../..  && rosdep install --from-paths src --ignore-src -r
```

- Compile your workspace with the new assignment:

```
$ catkin_make && rospack profile
```

Task 2: Lisp Homework

- Your Lisp assignment is in `assignment_2/src/...`
- (Re)start your Lisp REPL:

```
roslisp_repl &
```

- Load the package code:

```
CL-USER> (ros-load:load-system "assignment_2" :assignment-2)
```

- Change into package namespace:

```
CL-USER> (in-package :assignment-2)
```

- Follow the instructions in the `simple-world.lisp` file.
- Commit and push the changes once finished:

```
git add .
git commit -m "finished assignment_2"
git push my-repo master
```

Links

- Revenge of the nerds:
  http://www.paulgraham.com/icad.html
- Practical Common Lisp online book:
  http://www.gigamonkeys.com/book/
- The Little Schemer examples book:
  http://www.ccs.neu.edu/home/matthias/BTLS/

Info summary

Assignment:

- Due: 03.11., Wednesday, 23:59 German time
- Points: 10 points

Next class:

- Date: 04.11.
- Time: 14:15
- Place: same room (TAB 0.36)

Q & A

Thanks for your attention!