CSCI 334:
Principles of Programming Languages

Lecture 9: Lisp

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Announcements

Midterm exam *next* Thursday

Optional Lisp homework posted later today

Feedback: slides insufficient (clarification?)

Choosing a language

Many good technical reasons

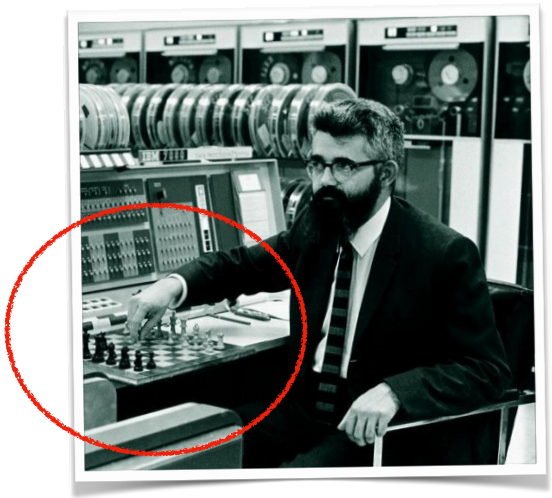
Few people decide for technical reasons

Seibel: Why do people get so religious about their computer languages?

Bloch: I don't know. But when you choose a language, you're choosing more than a set of technical trade-offs—you're choosing a community. It's like choosing a bar. Yes, you want to go to a bar that serves good drinks, but that's not the most important thing. It's who hangs out there and what they talk about. And that's the way you choose computer languages. Over time the community builds up around the language—not only the people, but the software artifacts: tools, libraries, and so forth. That's one of the reasons that sometimes languages that are, on paper, better than other languages don't win—because they just haven't built the right communities around themselves.

John McCarthy

IBM 704



Lisp was invented for AI research

```
                        04000       ORG 2048
04000 -0 53400 5 04011              LXD P1,J+K

04001 -0 63400 4 04020  P4          SXD P2,K
04002  0 50000 1 04022              CLA A+1,J
04003  1 77777 1 04004              TXI P6,J,-1
04004 -2 00001 4 04017  P6          TNX P5,K,1
04005  0 76500 0 00043  P3          LRS 35
04006  0 26000 0 04046              FMP X
04007  0 30000 1 04022              FAD A+1,J
04010  1 77777 1 04011              TXI P1,J,-1
04011  2 00001 4 04005  P1          TIX P3,K,1
04012  0 60100 0 04051              STO S
04013  0 56000 0 04050              LDQ Z
04014  0 26000 0 04047              FMP Y
04015  0 30000 0 04051              FAD S
04016 -3 77754 1                    TXL OUT, J,
                                      -N/2+1
04017  0 60100 0 04050  P5          STO Z
04020  1 00000 4 04001  P2          TXI P4,K
                        00005  N    EQU 5
                        00052  R    EQU N&N+3*N+2
                        04021  A    BSS R/2
04046  0 00000 0 00000  X
04047  0 00000 0 00000  Y
04050  0 00000 0 00000  Z
04051  0 00000 0 00000  S
                        00001  J    EQU 1
                        00004  K    EQU 4
                        04000       END P4-1
                        00000  OUT
```

704 Assembly (circa 1954)
(From Coding the MIT-IBM 704 Computer)

```
C                                                                       0114
C     READ IN INPUT DATA                                                0115
C                                                                       0116
      IF (ISYS-99) 401,403,401                                          0117
  403 READ TAPE 3,(G(I),I=1,8044)                                       0118
      REWIND 3                                                          0119
      IF (SENSE SWITCH 6) 651,719                                       0120
  401 ISYS=99                                                           0121
      IFROZ=0                                                           0122
      PAUSE 11111                                                       0123
  429 CALL INPUT                                                        0124
      IF (L) 651,651,433                                                0125
  433 WRITE OUTPUT TAPE 6,443, HX,VXPLS,VXMIN,HF,VFPLS,VFMIN            0126
     1, (ELMT(I),BOX(I),BOF(I),I=1,L)                                   0127
  443 FORMAT (10H1OXIDANT  3E16.6/10H FUEL      3E16.6/(1H A6,2E20.8))  0128
C                                                                       0129
C     RIGHT ADJUST ELEMENT SYMBOLS                                      0130
C                                                                       0131
      DO 447 K=1,L                                                      0132
      TMLM = ELMT(K)                                                    0133
      ELMT(K) = ARSF(24, TMLM)                                          0134
```

FORTRAN (circa 1956)
(From NASA Technical Note D-1737)

```
(defun fact (n)
    (cond ((eq n 0) 1)
          (t (* n (fact (- n 1))))))
```

LISP (circa 1958)

LISP is a "functional" language

- programs are modeled after math. functions
- no statements, only expressions
- no "mutable" variables, only declarations
- therefore, the effect of running a program ("evaluation") is purely the effect of applying a function to an input.

What does this mean?

- there is no hidden state (globals in C) or state-change rules (as in Java).
- complex parts are composed out of simple parts
- we care about what a program means and not what it does: you can understand a program without having to mentally execute it
- *programs are easier to reason about*

functional language (again)

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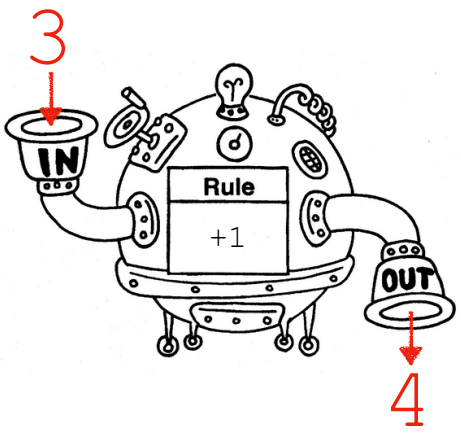
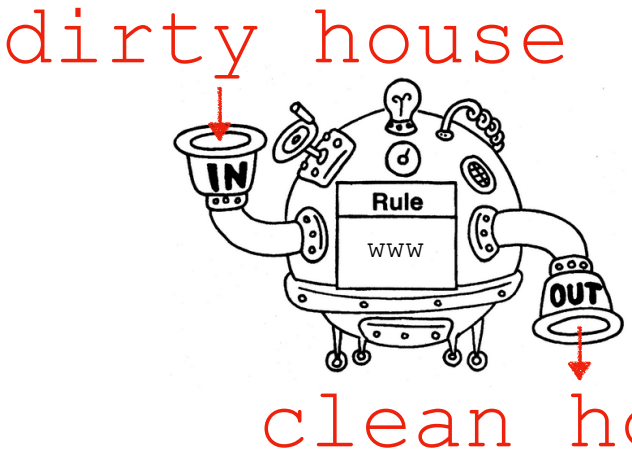
LISP is a “functional” language



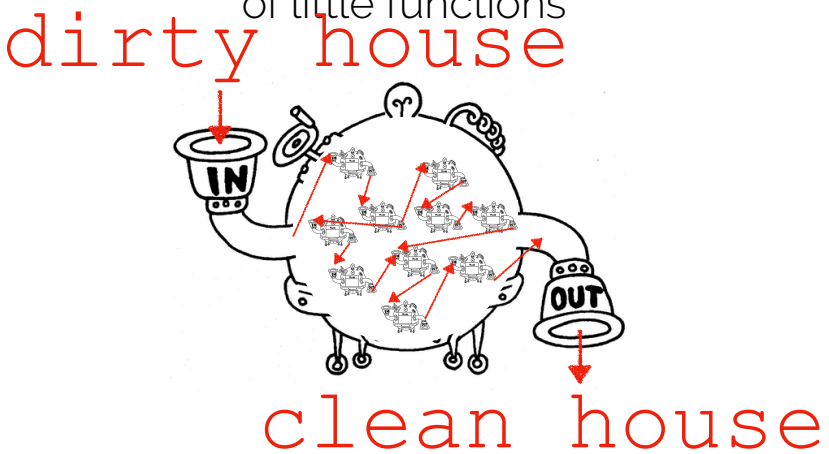

```
(defun add-one (n) (+ n 1))
```

LISP is a “functional” language



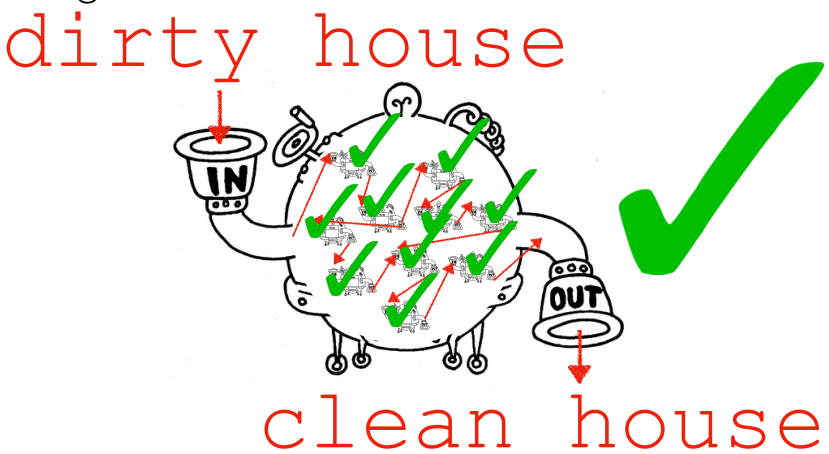

```
(defun cleaning-robot (dirt) …)
```

Big functions are “composed” of little functions




```
(defun cleaning-robot (dirt) …)
```

Program correctness is easier to achieve



I.e., whole is correct if pieces are correct.

LISP is inspired by the lambda calculus

- everything either a value or a funct. of a value

  value: `1`

  function of two values: `(+ 1 1)`
- syntax is (mind-numbingly) regular

  functions: `(function-name arguments …)`

  values: anything that is not a function
- evaluating a function produces a value:

  `(+ 1 1)` ↠ `2`

Statements vs. expressions

- A *statement* is an operation that changes the state of the computer

  Java: `i++`

  value stored at location i incremented by one
- An *expression* is a combination of functions and values that yields a new value

  Lisp: `(+ i 1)`

  evaluating `+` with i and `1` returns i `+` `1`

REPL
(read-eval-print loop)

Batch mode

Mutable variables

- If you can update a variable, your language has mutable variables

  Java: `int i = 3;`

  `i = 4;`
- Notice that both lines of code are statements
- (pure) Lisp does not have mutable variables

Immutable variables

- Variables cannot be updated in Lisp

  Lisp: `(defun my-func (i) …)`

  `(my-func 3)`

  or the shorter

  `((lambda (i) …) 3)`
- Notice that all of the above are expressions
- In fact, functions are the only way to bind values to names in (pure) Lisp

Lisp syntax: atoms

- An atom is the most basic unit in Lisp: data

  `4`

  `112.75`

  `"hello"`

  `'foo`

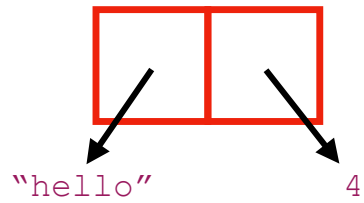
  `t`

  `nil`

Lisp syntax: cons cells

- cons cells are the basic unit of composition in Lisp (recall C composes data with `struct`).

  `(cons "hello" 4)`

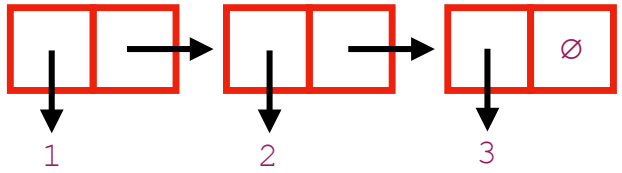


Lisp = LISt Processor

Lisp syntax: lists

- E.g., lists in Lisp are just made out of cons cells

```
(cons 1 (cons 2 (cons 3 nil)))
```



- Lisp has a shorthand for this:

```
'(1 2 3)
```

Lisp syntax: car and cdr

- Access the first element of a cons cell with `car`

```
(car (cons 1 2)) = 1
```

- Access the second element with `cdr`

```
(cdr (cons 1 2)) = 2
```

- What's the value of the following expression?

```
(car '(1 2 3))
```

- What about this?

```
(cdr '(1 2 3))
```

Lisp syntax: functions

- Everything else is a function (or special form)
- There are a bunch of built-in functions

```
(car …)
(cdr …)
(append …)
```

, etc.

- And you can define your own

```
(defun my-func (arg) (value))
```

Lisp syntax: conditionals

- In Lisp, there is no `if/else`

```
(cond ((test) (value)) …)
```

- E.g.,

```
(cond ((eq 1 x) (cons x xs)) …)
```

- Does the same as the Java

```
if (x == 1) {
  xs.add(x);
}
```

Lisp syntax: conditionals

- `cond` is more general than `if/else`.

```
(cond ((test1) (value1))
      ((test2) (value2)
      …)
```

```
(defun insert (x l)
  (cond ((eq l nil) (cons x nil))
        ((< x (car l)) (cons x l))
        (t (cons
             (car l)
             (insert x (cdr l))))))
```

That's pretty much it!

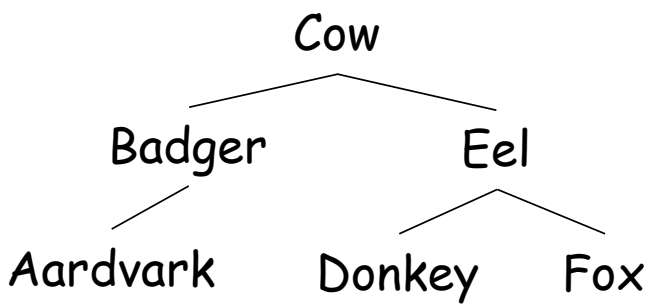
- See "334 Lisp FAQ" for all the syntax you need to know on course webpage
- If you happen to be looking at the book, a slightly different syntax is used (mostly Scheme).

Activity

list length

```
(length-list '(1 2 3 4 5 6)) → 6
```

Activity



Memory management

- C:

  When you want to use a variable, you have to *allocate* it first, then *decallocate* it when done.

```
MyObject *m = malloc(sizeof(MyObject));
m->foo = 2;
m->bar = 3;
… do stuff with m …
free(m);
```

Memory management

- Lisp and Java:

  You barely need to think about this at all.

```
MyObject m = new MyObject(2,3);
… do stuff with m …
(cons 2 3)
```