Lisp!

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January 6, 2015

Why Lisp?

- Great for symbolic computation
- Great for functional programming
- Learning Lisp will make you a better programmer in other languages
- Phillip Greenspun's Tenth Rule of Programming: "Any sufficiently complicated C or Fortran program contains an ad hoc, informally-specified bug-ridden slow implementation of half of Common Lisp."

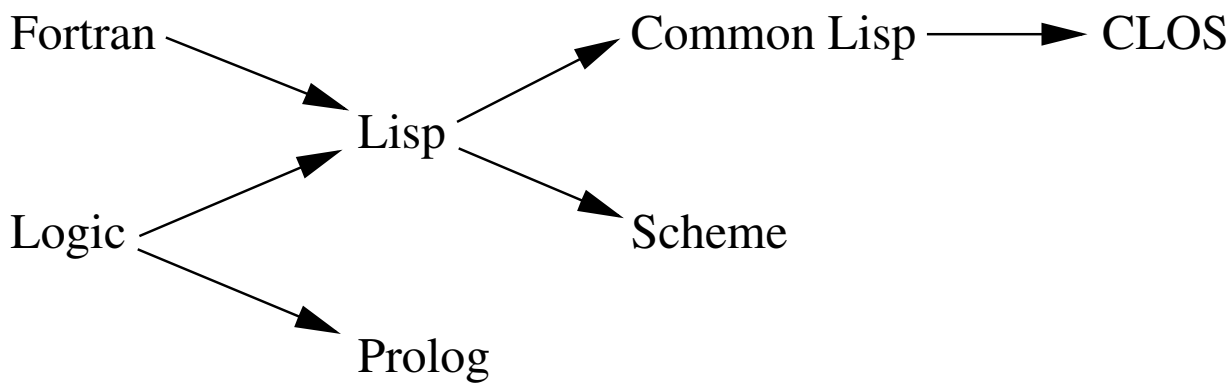
Symbolic Computation

- Differentiation:
  - General form: $a^d \Rightarrow da^{d-1}$
  - Application: $n^2 \Rightarrow 2n$
- DeMorgan's Law:
  - General form: $\neg(\phi \wedge \psi) \Rightarrow \neg\phi \vee \neg\psi$
  - Application: $\neg(\neg p \wedge q \rightarrow r) \Rightarrow \neg\neg p \vee \neg(q \rightarrow r)$

What is Lisp?

- Specified by John McCarthy in 1958
- LISP $\equiv$ LISt Processing
- Functional programming language
- Great for symbolic computing; important for AI tasks of the day
  - Predominant languages of the day were Fortran and COBOL
- Interpreted, but it can be compiled
- Great for rapid prototyping

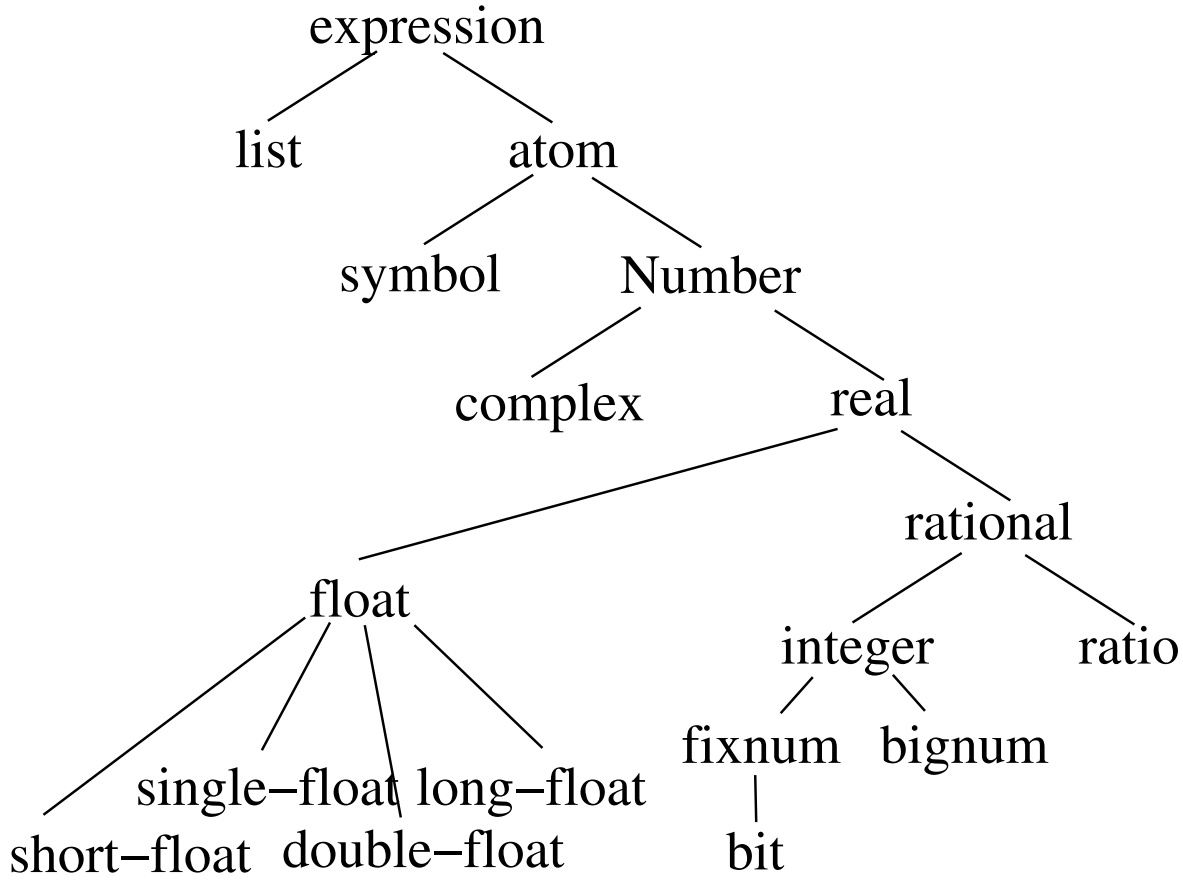
A Lineage of Lisp



Things to get your Head Around

- Most everything in Lisp is a list (a linked list)
  - OK, no big deal; I know about linked lists
- Lists can store elements of different types
  - OK, that's cool; I know about generic programming and class hierarchies
- Most everything is a function that returns a value
  - OK, that's fine; so, no void types. I got it.
- Functions, function calls, and control structures are also linked lists
  - Umm, but, aren't linked lists for storing and manipulating data?
- Consequently, there is no distinction between code and data
  - OK, now you lost me
- And then there are the parentheses...

Lisp Data Types

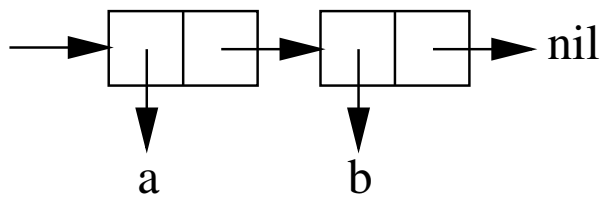


Lists and Function Calls

- We form lists and function calls using parentheses
- Prefix notation:
  - The first element of a list is the operator or function name
- Use a single quote to prevent evaluation
  - Empty list: `()`
  - List: `'(sqrt 4)`
  - Function Call: `(sqrt 4)`
  - If-statement: `(if pig 'cow 'dog)`
  - List: `'(if pig 'cow 'dog)`

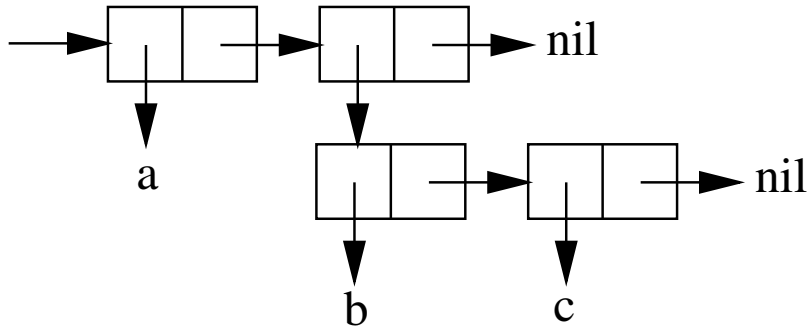
Linked Lists in Lisp

```
'(a b)
```



Linked Lists in Lisp

```
'(a (b c))
```



Numeric Operators and Functions

- `+`
- `-`
- `*`
- `sqrt`
- `1+`
- `1-`
- `min`
- `max`
- `expt`
- `log`
- `abs`
- `sin`, `cos`, `tan`
- `asin`, `acos`, `atan`
- `floor`, `ceiling`, `round`, `truncate`

Output Functions

- `(format` ⟨*file-stream*⟩ ⟨*control-string*⟩ ⟨*variable-list*⟩ `)`
- Example: `(format t "This is a test, ~a~%", 'bob)`
- Output: `This is a test, BOB`
- Basic control codes:
  - `~a` — any lisp object
  - `~s` — s-expression
  - `~d` — decimal
  - `~f` — float
  - `~%` — newline character

`prog1` Blocks

- Syntax:

  (`prog1`
  $\langle form_1 \rangle$
  $\langle form_2 \rangle$
  ...
  $\langle form_n \rangle$)

- Semantics:
  - Evaluates forms 1–n
  - `prog1` evaluates to the valuation of $\langle form_1 \rangle$

`progn` Blocks

- Syntax:

  (`progn`
  $\langle form_1 \rangle$
  $\langle form_2 \rangle$
  ...
  $\langle form_n \rangle$)

- Semantics:
  - Evaluates forms 1–n
  - `progn` evaluates to the valuation of $\langle form_n \rangle$

Defining Functions: `defun`

- Syntax:

  `(defun` ⟨*function-name*⟩ `(`⟨*parameter-list*⟩`)`
  ⟨*form*⟩`)`

- Semantics:
  - Defines a function with the name ⟨*function-name*⟩ with the parameters ⟨*parameter-list*⟩ and the body ⟨*form*⟩.
  - Evaluates to the function ⟨*function-name*⟩

Binding Local Variables: `let` and `let*`

- Syntax:

  (`let`[`*`] ((⟨*variable*$_1$⟩ ⟨*value*$_1$⟩)
  (⟨*variable*$_2$⟩ ⟨*value*$_2$⟩)
  ...
  (⟨*variable*$_n$⟩ ⟨*value*$_n$⟩))
  ⟨*form*⟩)

- Semantics:
  - Defines locally scoped variables 1–n
  - Binds or assigns values 1–n to variables 1–n, respectively
  - Evaluates ⟨*form*⟩
  - `let` evaluates to the valuation of ⟨*form*⟩
  - `let*` forces the sequential assignment of variables 1–n

Branching: `if-then-else`, `when`, `unless`

- Syntax:

  `(if` ⟨*test*⟩
  ⟨*then-form*⟩
  [⟨*else-form*⟩])

- Semantics:
  - Evaluates ⟨*test*⟩
  - If ⟨*test*⟩ is not `nil`, evaluates ⟨*then-form*⟩
  - Otherwise, if ⟨*else-form*⟩ is not `nil`, evaluates ⟨*else-form*⟩
  - `if` evaluates to the form evaluated
- Also:
  - `(when` ⟨*test*⟩ ⟨*form*⟩`)` ≡ `(if` ⟨*test*⟩ ⟨*then-form*⟩`)`
  - `(unless` ⟨*test*⟩ ⟨*form*⟩`)` ≡ `(if` ⟨*test*⟩ `nil` ⟨*else-form*⟩`)`
  - `(unless (not` ⟨*test*⟩`)` ⟨*form*⟩`)` ≡ `(if (not` ⟨*test*⟩`)` ⟨*then-form*⟩`)`

Relational and Equality Operators and Functions

- `equalp` — same expression?
- `equal` — same expression?
- `eql` — same symbol or number?
- `eq` — same symbol?
- = — same number?
- `atom` — is it an atom?
- `numberp` — is it a number?
- `consp` — is it a cons?
- `listp` — is it a list?
- `symbolp` — is it a symbol?
- `boundp` — is it a bound symbol?
- Also `member`, `null`, `zerop`, `plusp`, `minusp`, `evenp`, `oddp`, <, <=, >=, and >.

Nested if-then-else Statements: `cond`

- Syntax:

  `(cond (`$\langle test_1 \rangle$ $\langle consequent_1 \rangle$`)`
  `(`$\langle test_2 \rangle$ $\langle consequent_2 \rangle$`)`
  `...`
  `(`$\langle test_n \rangle$ $\langle consequent_n \rangle$`))`

- Semantics:
  - Evaluates tests 1–n
  - Evaluates the consequent of the first test that is not `nil`
  - `cond` evaluates to the valuation of the consequent or to `nil` if no test is not `nil`
  - Note that the literal `t` always evaluates to true

Looping through Lists: `dolist`

- Syntax:

  `(dolist (`⟨*variable*⟩ ⟨*list-form*⟩ `[`⟨*result-form*⟩`])`
  ⟨*form*⟩`)`

- Semantics:
  - Iterates once for each element in ⟨*list-form*⟩
  - Assigns the element to ⟨*variable*⟩
  - Evaluates ⟨*form*⟩
  - Upon loop termination, evaluates ⟨*result-form*⟩
  - `dolist` evaluates to the valuation of ⟨*result-form*⟩

Count-controlled Loops: `dotimes`

- Syntax:

  `(dotimes (`⟨*variable*⟩ ⟨*upper-bound-form*⟩ `[`⟨*result-form*⟩`])`
  ⟨*form*⟩`)`

- Semantics:
  - Iterates over $[0, \langle \textit{upper-bound-form} \rangle)$
  - Assigns the counter value to ⟨*variable*⟩
  - Evaluates ⟨*form*⟩
  - Upon loop termination, evaluates ⟨*result-form*⟩
  - `dotimes` evaluates to the valuation of ⟨*result-form*⟩

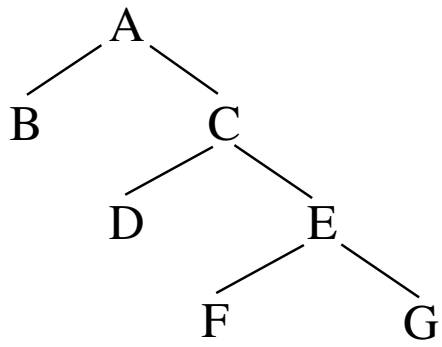
General Looping Construct: `do` and `do*`

- Syntax:

  (`do`[`*`]((⟨var_1⟩ ⟨$init_1$⟩ ⟨$update_1$⟩)
  (⟨var_2⟩ ⟨$init_2$⟩ ⟨$update_2$⟩)
  ...
  (⟨var_n⟩ ⟨$init_n$⟩ ⟨$update_n$⟩)
  (⟨*termination-test*⟩ ⟨*result-form*⟩))
  ⟨*form*⟩)

- Semantics:
  - Defines locally scoped variables ⟨var_i⟩
  - Initializes them to ⟨$init_i$⟩
  - Loops until ⟨*termination-test*⟩ is not `nil` by
    - updating ⟨var_i⟩ by evaluating ⟨$update_i$⟩
    - evaluating ⟨*form*⟩
  - Upon loop termination, evaluates ⟨*result-form*⟩
  - `do` evaluates to the valuation of ⟨*result-form*⟩
  - `do*` forces the sequential assignment of ⟨var_i⟩

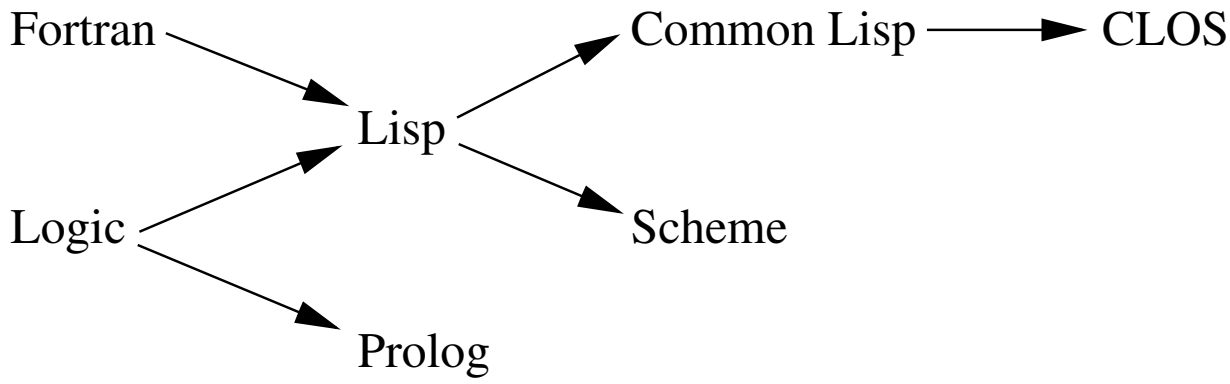
Binary Trees




```
(A (B nil nil)
   (C (D nil nil)
      (E (F nil nil)
         (G nil nil))))

(A (B)
   (C (D)
   (E (F)
      (G))))
```

Graphs




```
(setf (get 'fortran 'influenced) '(lisp))
(setf (get 'logic 'influenced) '(lisp prolog))
(setf (get 'lisp 'influenced) '(scheme common-lisp))
(setf (get 'common-lisp 'influenced) '(clos))
```

Things We Won't Cover

- Dotted Lists
- Types
- Strings
- Serious File I/O
- Packages
- Hash Tables
- Structures (aka records)
- Exceptions: throw and catch
- Programmer-defined macros
- CLOS: classes, properties, methods
- Many, many functions, forms, and macros