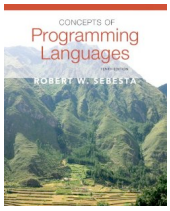
CSC 533: Programming Languages

Spring 2015

See online syllabus at:

http://dave-reed.com/csc533



Course goals:

- understand issues in designing, implementing, and evaluating programming languages
- appreciate strengths and tradeoffs of different programming paradigms
- working knowledge of Java, Scheme, & a modern scripting language

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Why are there different programming languages?

in theory, all programming languages are equivalent

- compiled/interpreted into basic machine operations
- Church-Turing thesis applies

Why are there different natural languages?

in practice, different languages provide distinct voices

- different cultures (application domains)
- different primitive concepts (operations)
- different ways of thinking about the world (perspectives)

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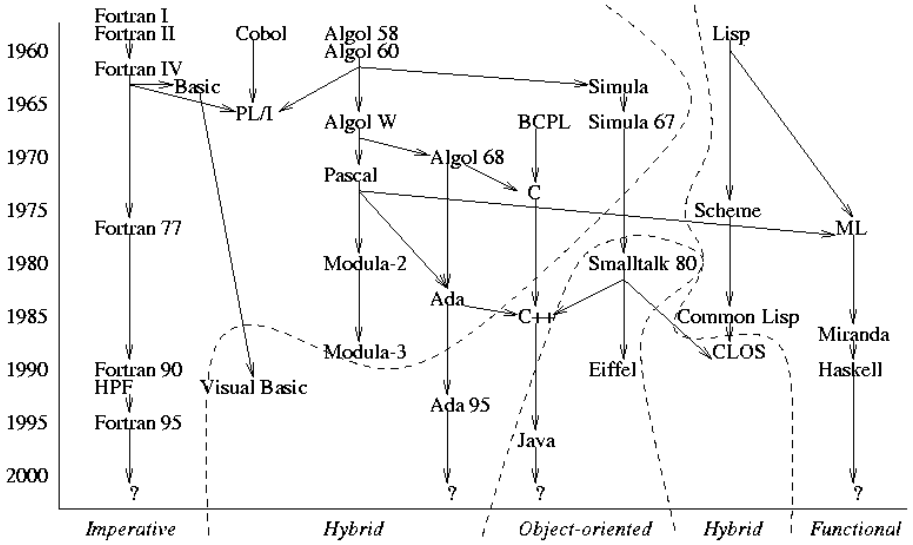
Family tree of (some) high-level languages



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Programming paradigms

similarly, different problem-solving approaches (paradigms) exist and are better suited to different types of tasks

imperative approaches: programs specify sequences of state changes

- *procedure-oriented*: subroutines & nested scopes (Pascal, C)
- *object-based*: interacting objects (Ada, Modula)
- *object-oriented*: objects + inheritance (C++, Java, Smalltalk)

functional approach: programs transform data by applying functions

- e.g., LISP/Scheme, ML, Haskell

logic approach: programs are statements in logic that describe a solution

- *e.g., Prolog, Oz*

scripting? visual? concurrent?

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Example: Circle of Friends

consider a group of friends

- note: friends are not necessarily bidirectional (?)

  Amy is friends with Bob, Dan, and Elle
  Bob is friends with Amy and Dan
  Chris is friends with Dan and Elle
  Dan is friends with Chris
  Elle is friends with Amy, Bob, Chris and Dan

- we can define a circle of friends:

  circle (level 1) of Dan = direct friends of Dan = {Chris}
  circle (level 2) of Dan = direct friends of Dan + their direct friends – Dan
  = {Chris} + {Dan, Elle} – Dan
  = {Chris, Elle}

  circle (level N) of Dan = circle (level N-1) of Dan + their direct friends – Dan

suppose we want to enter a collection of friends and determine friend circles

- solution in Java? input format? data structures? algorithm?

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Example: Circle of Friends in LISP/Scheme

this problem is ideal for Scheme

- Scheme is a functional programming language
- it is symbolic, can represent words and text as easily as numbers
- it has primitives for manipulating lists and structures
- recursion is natural and efficient

```
(define FRIENDS
  '((amy (bob dan elle))
    (bob (amy dan))
    (chaz (dan elle))
    (dan (chaz))
    (elle (amy bob chaz dan))))


(define (getFriends person)
  (cadr (assoc person FRIENDS)))

(define (getCircle person distance)
  (if (= distance 1)
      (getFriends person)
      (let ((circle (getCircle person (- distance 1))))
        (remove person
                (remove-duplicates (append circle
                                           (apply append (map getFriends circle))))))))
```

can compactly represent the friends as nested lists

can write the basic code in 7-9 lines

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Why study programming languages?

increased capacity to express ideas
- broader perspective on programming and problem solving, new paradigms

improved background for choosing appropriate languages
- know tradeoffs between different languages
- simplify programming task by choosing best-suited language

increased ability to learn new languages
- as with natural languages, 2nd language is hardest to learn
- languages come and go, must be able to adapt/adjust

better understanding of the significance of implementation
- can use language more intelligently if understand implementation
- also aids in identifying bugs

increased ability to design/implement new languages

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How do we judge a programming language?

readability

in software engineering, maintenance cost/time far exceeds development cost/time
→ want code to be easy to understand, modify, and maintain

- *simplicity:* language should be as small as possible, avoid redundant features
  - C++ is pretty complex, e.g., `x++;` `++x;` `x +=1;` `x = x + 1;`
  - Java slightly better (some features removed); Scheme is very simple
- *orthogonality:* small set of primitive constructs, can be combined independently and uniformly (i.e., very few special cases)
  - C++ is OK but many exceptions, e.g., functions can return structs, not arrays
  - Java slightly better; Scheme is highly orthogonal
- *natural control and data structures:* provide useful, high-level abstractions
  - C++ is good but does include some tricky ones, e.g., `:?, goto`
  - Java comparable (but no `goto`); Scheme is limited (e.g., recursion for looping)
- *simple and unambiguous syntax:* intended form of code is clear to reader
  - C++ not so good, e.g., overall complexity, dangling else, overused `static`
  - Java slightly better; Scheme syntax is simple and clear

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How do we judge a programming language (cont.)?

writability

want to make programming as simple as possible for the programmer

- *simplicity + orthogonality + natural control & data structures + simple & unambiguous syntax*
- *support for abstraction:* need to be able to define and utilize abstractions
  - C++ is good, e.g., support for functions, libraries, classes
  - Java is comparable; Scheme is OK, but more tedious
- *expressivity:* language provides convenient ways of specifying computations
  - C++ is good, e.g., if & switch, while & do-while & for, bitwise operators, …
  - Java is slightly less (removes low-level); Scheme is not very expressive (few control structures)

note: readability & writability are often at odds

e.g., more control structures can simplify programmer's task, but make code harder to read and maintain (more to know, more redundancy)

Common LISP vs. Scheme

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How do we judge a programming language (cont.)?

reliability

want to ensure that a program performs to its specifications under all conditions

→want to build in strong error checking and recovery capabilities

→also want to help the programmer to avoid errors

- *readability + writability*
- *type checking:* identify errors either at compile-time or during execution
  - C++ is pretty good, e.g., most types checked at compile time, some loopholes
  - Java is slightly better; Scheme is dynamic, must do checking during execution
- *exception handling:* ability to intercept and recover from errors in code
  - C++ is OK (try/catch, but not always used)
  - Java is slightly better (libraries require exception handling), Scheme is more awkward
- *memory management:* control memory accessing, allocation/deallocation, aliasing
  - C++ is *dangerous*, e.g., can access specific addresses, must deallocate memory
  - Java is better (memory mgmt is automatic); Scheme handles all transparently

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