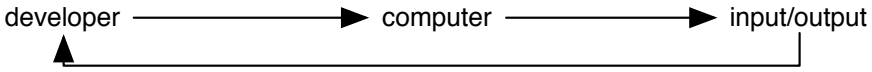
Programming Languages: The Big Picture

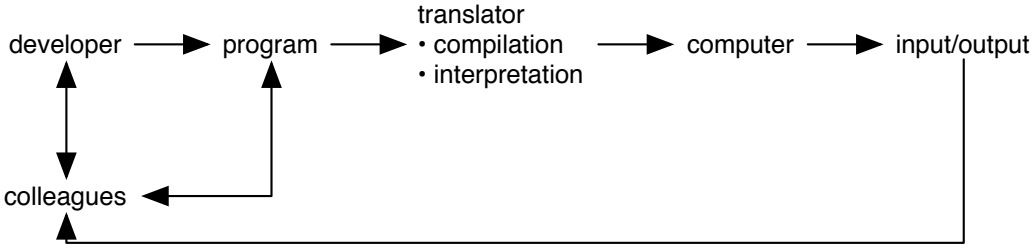
" Instead of imagining that our main task is to instruct a computer what to do, let us concentrate rather on explaining to human beings what we want a computer to do."

— Don Knuth, *Literate Programming*, 1984

Absolute top-level bird's eye view:



A little closer, in today's highly collaborative environment:



A Brief History of Programming Languages

Initial focus: machine-centric programming

- Machine language — the exact bits that control a processor's operations
- Assembly language — machine language with mnemonics (e.g. *sw* [store word] instead of *10101111101*)
- Assembly language with macro expansion — support for programmer-specified abbreviations of frequent assembly constructs or parameters

Shift to machine independence

- Eliminate the need to rewrite the same program for multiple machines
- "High-level" languages (and their clever acronyms) — Fortran (*For*mula *Tran*slator), Lisp (*Lis*t *P*rocessing), Algol (*Algo*rithmic *L*anguage)
- The *compiler* is born — no more one-to-one correspondence between programmed symbols and machine instructions
- Originally, compiled programs were viewed as a slower alternative to directly-written assembly
- Advances in compiler technology and increased sophistication of software have reversed that

Programming Language Diversity

So many languages, so little time — why isn't there "one true programming language?"

- *Evolution* — ongoing shifts in programming paradigms: structured programming, object-oriented programming, document-centric languages…
- *Special purposes* — many languages are (initially) designed for a specific domain
- *Personal preference* — individual tastes, aptitudes

Characteristics of "Successful" Languages

- *Expressive power* — though theoretically all equivalent, some languages can do more with less work
- *Learning curve* — or, the opposite of "barrier to entry"
- *Ease of implementation* — elimination of another "barrier to entry" — how easy is it to get a language onto your machine of choice?
- *Compiler quality* — can be extended to "development tool quality"
- *Non-technical factors* — "economics, patronage, inertia"

A Language for Everything

Programming languages

- declarative
  - functional: Lisp/Scheme, ML, Haskell
  - data flow: Id, Val
  - logic, constraint-based: Prolog, VisiCalc
- imperative
  - Von Neumann: Fortran, Pascal, Basic, C
  - object-oriented: Smalltalk, Eiffel, C++, Java
  - "dynamic" (a.k.a. scripting): Perl, JavaScript

"Other" languages

- What is "programming," and what is not?
- document specification
  - "paper-like" documents: HTML, XML, LaTeX
  - graphs and diagrams: ER, UML
- information systems
  - querying: SQL, Query-by-Example
  - data/object definition: SQL, ER, UML
- focused applications
  - development: make, ant
  - game scripting: QuakeC, UnrealScript
  - multimedia: ActionScript (formerly known as Lingo)

Programming Workflows

- source code ➡ *compiler* ➡ target program

  input ➡ *target program* ➡ output

- source code, input ➡ *interpreter* ➡ output

- source code ➡ *translator* ➡ intermediate code

  intermediate code, input ➡ *virtual machine* ➡ output

Compiler Strategies, Variations

- *Code reuse: libraries* — break up compilation into compilation + linking
- *Ease of debugging, machine abstraction* — compile to assembly language, not direct to machine code
- *Comments, macros, directives* — preprocessor prior to compilation, resulting in intermediate source code
- *High-level machine abstraction: the "virtual machine"* — compile to an intermediate mode that is "interpreted" by the virtual machine

Compilation Overview

- Understanding the compilation process is a key cornerstone to many skills:
  - Error analysis and resolution
  - Mapping corresponding concepts across languages
  - Creating appropriate layers of abstraction
- Two major phases
  - Determine the meaning of a program — *front end*
  - Construct an equivalent target program — *back end*