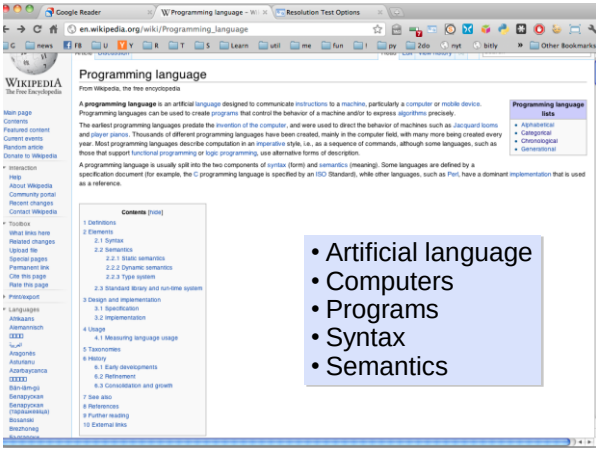
Programming Languages

Introduction

Overview

- **Motivation**
- **Why study programming languages?**
- **Some key concepts**

What is a programming language?



What is a programming language?

"…there is no agreement on what a programming language really is and what its main purpose is supposed to be. Is a programming language a tool for instructing machines? A means of communicating between programmers? A vehicle for expressing high-level designs? A notation for algorithms? A way of expressing relationships between concepts? A tool for experimentation? A means of controlling computerized devices? My view is that a general-purpose programming language must be all of those to serve its diverse set of users. The only thing a language cannot be – and survive – is a mere collection of ''neat'' features."

-- Bjarne Stroustrup, The Design and Evolution of C++
http://cs.umbc.edu/courses/331/papers/dne_notes.pdf

On language and thought (1)

- Idea: language effects thought

  "A strong version of the hypothesis holds that language determines thought and that linguistic categories limit and determine cognitive categories. A weaker version states that linguistic categories and usage influence thought and certain kinds of non-linguistic behaviour." – Wikipedia

- Still controversial for natural languages: eskimos, numbers, etc.

  –See Does Your Language Shape How You Think?

- Does a choice of a programming language effect the program 'ideas' you can express?

On language and thought (2)

- "The tools we use have a profound (and devious!) influence on our thinking habits, and therefore, on our thinking abilities." -- Edsger Dijkstra, *How do we tell truths that might hurt*
- "A language that doesn't affect the way you think about programming, is not worth knowing" -- Alan Perlis

Additional Personal Thoughts

Sometimes, language follows thought, doesn't lead it:

- Cannot conceive of that which you cannot imagine, cannot convey that which you cannot describe, but…
- However, you can often cobble together descriptions of nearly-arbitrary concepts w/limited vocabularies
  - E.g. 1: Korean: no plurals
  - E.g. 2: Chinese: no gendered pronouns
  - E.g. 3: C++ in C: OOP initially implemented as a set of C macros

Additional Personal Thoughts

Languages sometimes do drive thought:

- People say French is a romantic language
- Gendered nouns affect thoughts
- In programming:
  - E.g. 1: Thinking "object-orientedly"
  - E.g. 2: Logic programming: no procedural thoughts!

Additional Personal Thoughts

Relevance to studying programming languages:

- We should study many PLs, for:
  - Inspiration: e.g., OOP
  - Using proper tool:
    - » "to a hammer…" (but a hammer *can* be used for many things, clumsily)
  - Efficiency: need to be able to build on existing artifacts, instead of re-implementing

Some General Underlying Issues

- Why study PL concepts?
- Programming domains
- PL evaluation criteria
- What influences PL design?
- Tradeoffs faced by programming languages
- Implementation methods
- Programming environments

Why study Programming Language Concepts?

- Increased capacity to express programming concepts
- Improved background for choosing appropriate languages
- Enhanced ability to learn new languages
- Improved understanding of the significance of implementation
- Increased ability to design new languages
- Mastering different programming paradigms

Programming Domains

- Scientific applications
- Business applications
- Artificial intelligence
- Systems programming
- Scripting languages
- Special purpose languages
- *Mobile, eductional, Web, massively parallel, …*

Language Evaluation Criteria

- Readability
- Writability
- Reliability
- Cost
- Etc…

Evaluation Criteria: Readability

- How easy is it to read and understand programs written in the programming language?
- Arguably the most important criterion!
- Factors effecting readability include:
  - **Overall simplicity:** too many features is bad, as is a multiplicity of features (multiple ways to do same thing)
  - **Orthogonality**: a relatively small set of primitive constructs combinable in a relatively small number of ways to build the language's control and data structures
    - »Makes the language easy to learn and read
    - »Meaning is context independent
  - **Control statements**
  - **Data type and structures**
  - **Syntax considerations**

Evaluation Criteria: Writability

How easy is it to write programs in the language?

Factors effecting writability:

- Simplicity and orthogonality
- Support for abstraction
- Expressivity
- Fit for the domain and problem

Evaluation Criteria: Reliability

Factors:

- Type checking
- Exception handling
- Aliasing
- Readability and writability

Evaluation Criteria: Cost

Categories:

- Programmer training
- Software creation
- Compilation
- Execution
- Compiler cost
- Poor reliability
- Maintenance

Evaluation Criteria: others

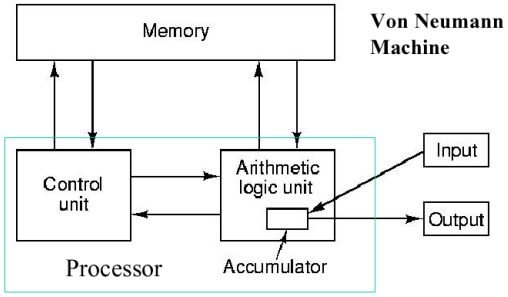
- Portability
- Generality
- Well-definedness
- Good fit for hardware (e.g., cell) or environment (e.g., Web)
- etc…

Language Design Influences

Computer architecture

- We use **imperative** languages, at least in part, because we use **von Neumann** machines
  - John von Neuman is generally considered to be the inventor of the "stored program" machines, the class to which most of today's computers belong
  - One CPU + one memory system that contains *both* program and data
- Focus on moving data and program instructions between registers in CPU to memory locations
- Fundamentally sequential

Von Neumann Architecture



Language Design Influences:

Programming methodologies

- *50s and early 60s:* Simple applications; worry about machine efficiency
- *Late 60s:* People efficiency became important; readability, better control structures. maintainability
- *Late 70s:* Data abstraction
- *Middle 80s:* Object-oriented programming
- *90s:* distributed programs, Internet
- *00s:* Web, user interfaces, graphics, mobile, services
- *10s: parallel computing,* cloud computing*?*, pervasive computing?, semantic computing?, virtual machines?

Language Categories

The big four PL paradigms:

- Imperative or procedural (e.g., Fortran, C)
- Object-oriented (e.g. Smalltalk, Java)
- Functional (e.g., Lisp, ML)
- Rule based (e.g. Prolog, Jess)

Others:

Scripting (e.g., Python, Perl, PHP, Ruby)
Constraint (e.g., Eclipse)
Concurrent (Occam)
…

Language Design Trade-offs

Reliability versus cost of execution
Ada, unlike C, checks all array indices to ensure proper range but has very expensive compilation

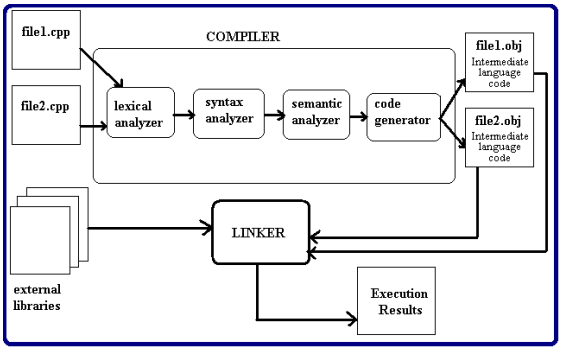
Writability versus readability
(2 = 0 +.= T o.| T) / T <- iN
APL one-liner producing prime numbers from 1 to N, obscure to all but the author

Flexibility versus safety
C, unlike Java, allows one to do arithmetic on pointers, see worse is better

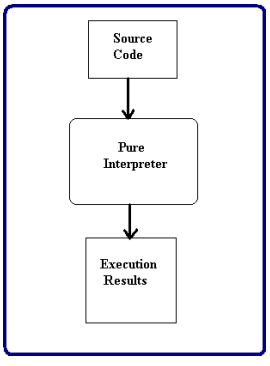
Implementation methods

- **Direct execution by hardware**
  e.g., native machine language
- **Compilation to another language**
  e.g., C compiled to native machine language for Intel Pentium 4
- **Interpretation: direct execution by software**
  e.g., csh, Lisp (traditionally), Python, JavaScript
- **Hybrid: compilation then interpretation**
  Compilation to another language (aka bytecode), then interpreted by a 'virtual machine', e.g., Java, Perl
- **Just-in-time compilation**
  Dynamically compile some bytecode to native code (e.g., V8 javascript engine)

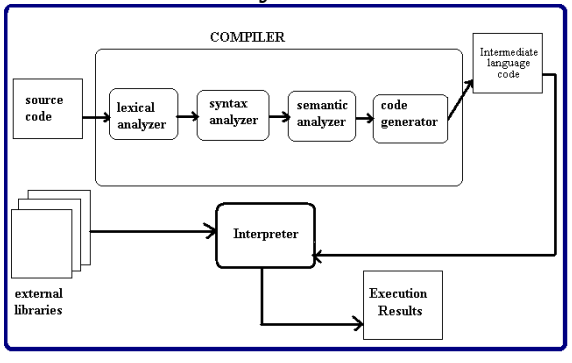
Compilation



Interpretation

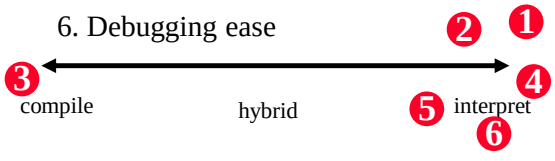


Hybrid



Implementation issues

1. Complexity of compiler/interpreter
2. Translation speed
3. Execution speed
4. Code portability
5. Code compactness
6. Debugging ease



Programming Environments

- Collection of tools used in software development, often including an integrated editor, debugger, compiler, collaboration tool, etc.
- Modern Integrated Development Environments (IDEs) tend to be language specific, allowing them to offer support at the level at which the programmer thinks.
- Examples:
  - UNIX -- Operating system with tool collection
  - EMACS – a highly programmable text editor
  - Smalltalk -- A language processor/environment
  - Microsoft Visual C++ -- A large, complex visual environment
  - Your favorite Java environment: BlueJ, Jbuilder, J++, …
  - Generic: IBM's Eclipse

Summary

- Programming languages have many aspects & uses
- There are many reasons to study the concepts underlying programming languages
- There are several criteria for evaluating PLs
- Programming languages are constantly evolving
- Classic techniques for executing PLs are compilation and interpretation, with variations