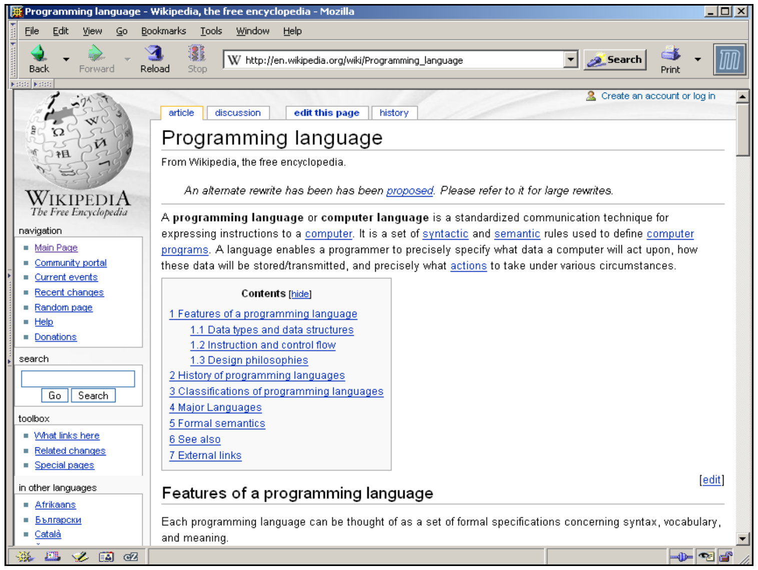
Programming Languages

Introduction

Overview

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

What is a programming language?



Programming language

From Wikipedia, the free encyclopedia.

An alternate rewrite has been has been proposed. Please refer to it for large rewrites.

A **programming language** or **computer language** is a standardized communication technique for expressing instructions to a computer. It is a set of syntactic and semantic rules used to define computer programs. A language enables a programmer to precisely specify what data a computer will act upon, how these data will be stored/transmitted, and precisely what actions to take under various circumstances.

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Features of a programming language

Each programming language can be thought of as a set of formal specifications concerning syntax, vocabulary, and meaning.

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://www.cs.umbc.edu/331/papers/dne_notes.pdf

On language and thought (1)

Idea: language effects thought

"The Language of Thought Hypothesis (LOTH) postulates that thought and thinking take place in a mental language. This language consists of a system of representations that is physically realized in the brain of thinkers and has a combinatorial syntax (and semantics) such that operations on representations are causally sensitive only to the syntactic properties of representations. …"

-- Stanford Encyclopedia of Philosophy

-- http://plato.stanford.edu/entries/language-thought/

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

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?*,

http://www.cs.umbc.edu/331/papers/ewd498.htm

Edsger Wybe Dijkstra (11 May 1930 -- 6 August 2002), http://www.cs.utexas.edu/users/EWD/

Professor Edsger Wybe Dijkstra, a noted pioneer of the science and industry of computing, died after a long struggle with cancer on 6 August 2002 at his home in Neunen, the Netherlands.

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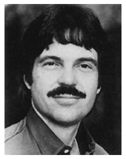
On languages and thought (3)



"What doesn't exist are really powerful general forms of arguing with computers right now. So we have to have special orders coming in on special cases and then think up ways to do it. Some of these are generalizable and eventually you will get an actual engineering discipline."

-- Alan Kay, Educom Review

Alan Kay is one of the inventors of the Smalltalk programming language and one of the fathers of the idea of OOP. He is the conceiver of the laptop computer and the architect of the modern windowing GUI.

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

Language Evaluation Criteria

- Readability
- Writability
- Reliability
- Cost
- Etc…

Evaluation Criteria: Readability

- How easy is it to read and understand programs written in the PL?
- Arguably the most important criterion!
- Factors effecting readability include:
  - –Overall simplicity
    - »Too many features is bad as is a multiplicity of features
  - –Orthogonality
    - »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

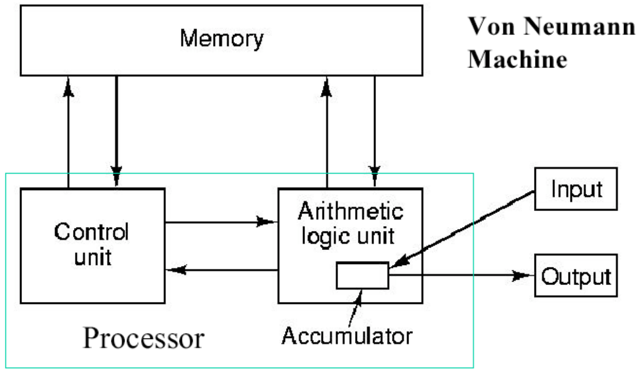
- Portability
- Generality
- Well-definedness
- Good fit for hardware (e.g., cell) or environment (e.g., Web)
- etc…

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
  - CPU+memory which contains both program & data
- Focus on moving data and program instructions between registers in CPU to memory locations

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, Web
- *00s:* cloud computing*?,* mobile/pervasive computing?, Web 2.0?, Web services?, virtual worlds?

Language Categories

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

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.

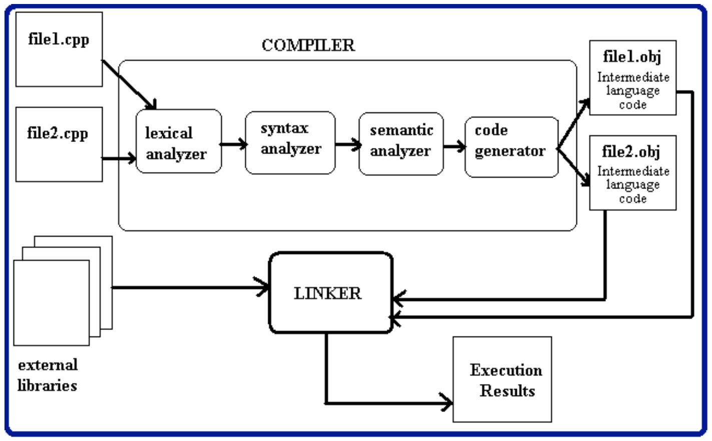
Writability versus readability
(2 = 0 +.= T o.| T) / T <- iN
APL one-liner producing prime numbers from 1 to N

Flexibility versus safety
C, unlike Java, allows one to do arithmetic on pointers.

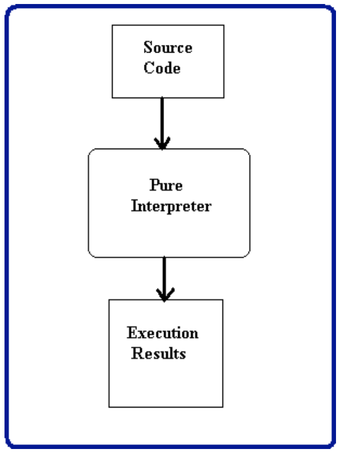
Implementation methods

- **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)

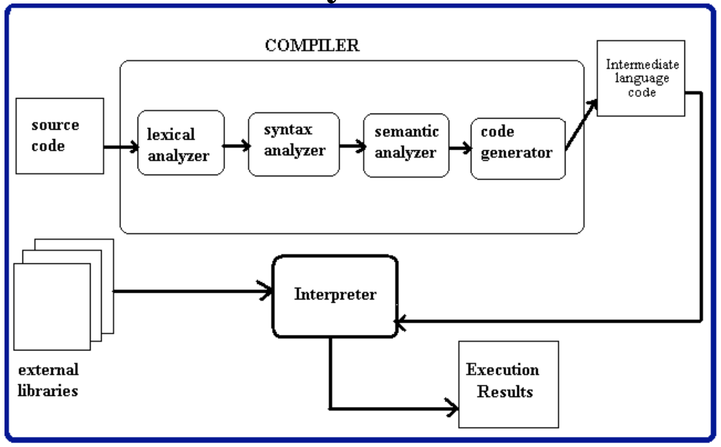
Compilation



Interpretation

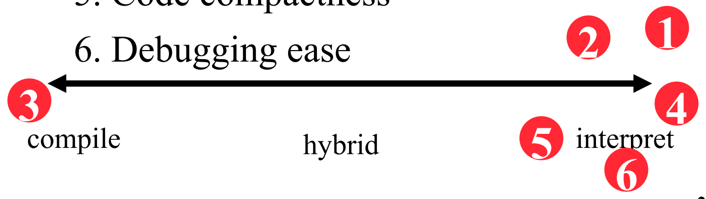


Hybrid



Implementation issues

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



Programming Environments

- The 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