Chapter 1 – Preliminaries

Chapter 1 Topics

Reasons for Studying Concepts of Programming Languages

Programming Domains

Language Evaluation Criteria

Influences on Language Design

Language Categories

Language Design Trade-Offs

Implementation Methods

Programming Environments

Reasons for Studying Concepts of Programming Languages

Increased ability to express ideas

Improved background for choosing appropriate languages

Increased ability to learn new languages

Better understanding of significance of implementation

Better use of languages that are already known

Overall advancement of computing

Programming Domains

Scientific applications

Large numbers of floating point computations; use of arrays

Fortran

Business applications

Produce reports, use decimal numbers and characters

COBOL

Artificial intelligence

Symbols rather than numbers manipulated; use of linked lists

LISP

Systems programming

Need efficiency because of continuous use

C

Web Software

Eclectic collection of languages: markup (e.g., XHTML), scripting (e.g., PHP), general-purpose (e.g., Java)

Language Evaluation Criteria

Readability: the ease with which programs can be read and understood

Writability: the ease with which a language can be used to create programs

Reliability: conformance to specifications (i.e., performs to its specifications)

Cost: the ultimate total cost

Evaluation Criteria: Readability

Overall simplicity

A manageable set of features and constructs

Minimal feature multiplicity

Minimal operator overloading

Orthogonality

A relatively small set of primitive constructs can be combined in a relatively small number of ways

Every possible combination is legal

Data types

Adequate predefined data types

Syntax considerations

Identifier forms: flexible composition

Special words and methods of forming compound statements

Form and meaning: self-descriptive constructs, meaningful keywords

Evaluation Criteria: Writability

Simplicity and orthogonality

Few constructs, a small number of primitives, a small set of rules for combining them

Support for abstraction

The ability to define and use complex structures or operations in ways that allow details to be ignored

Expressivity

A set of relatively convenient ways of specifying operations

Strength and number of operators and predefined functions

Evaluation Criteria: Reliability

Type checking

Testing for type errors

Exception handling

Intercept run-time errors and take corrective measures

Aliasing

Presence of two or more distinct referencing methods for the same memory location

Readability and writability

A language that does not support "natural" ways of expressing an algorithm will require the use of "unnatural" approaches, and hence reduced reliability

Evaluation Criteria: Cost

Training programmers to use the language

Writing programs (closeness to particular applications)

Compiling programs

Executing programs

Language implementation system: availability of free compilers

Reliability: poor reliability leads to high costs

Maintaining programs

Evaluation Criteria: Others

Portability

The ease with which programs can be moved from one implementation to another

Generality

The applicability to a wide range of applications

Well-definedness

The completeness and precision of the language's official definition

Influences on Language Design

Computer Architecture

Languages are developed around the prevalent computer architecture, known as the *von Neumann* architecture

Programming Methodologies

New software development methodologies (e.g., object-oriented software development) led to new programming paradigms and by extension, new programming languages

Computer Architecture Influence

Well-known computer architecture: Von Neumann

Imperative languages, most dominant, because of von Neumann computers

Data and programs stored in memory

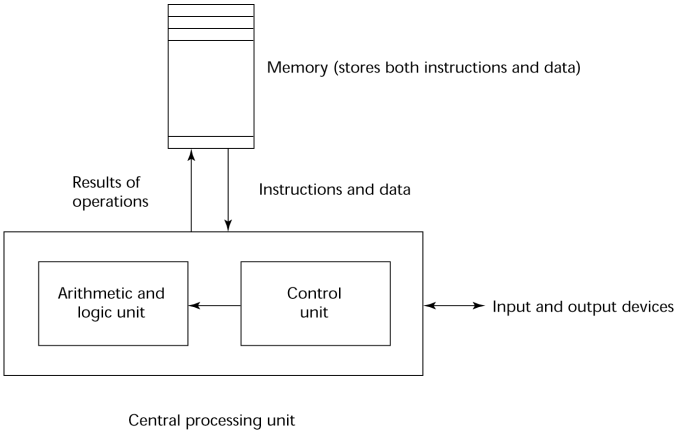
Memory is separate from CPU

Instructions and data are piped from memory to CPU

Basis for imperative languages

- Variables model memory cells
- Assignment statements model piping
- Iteration is efficient

The von Neumann Architecture



Fetch-execute-cycle (on a von Neumann architecture computer)

```
initialize the program counter
repeat forever
    fetch the instruction pointed by the counter
    increment the counter
    decode the instruction
    execute the instruction
end repeat
```

Programming Methodologies Influences

1950s and early 1960s: Simple applications; worry about machine efficiency

Late 1960s: People efficiency became important; readability, better control structures

structured programming

top-down design and step-wise refinement

Late 1970s: Process-oriented to data-oriented

data abstraction

Middle 1980s: Object-oriented programming

Data abstraction + inheritance + polymorphism

Language Categories

Imperative

Central features are variables, assignment statements, and iteration

Include languages that support object-oriented programming

Include scripting languages

Include the visual languages

Examples: C, Java, Perl, JavaScript, Visual BASIC .NET, C++

Functional

Main means of making computations is by applying functions to given parameters

Examples: LISP, Scheme

Logic

Rule-based (rules are specified in no particular order)

Example: Prolog

Markup/programming hybrid

Markup languages extended to support some programming

Examples: JSTL, XSLT

Language Design Trade-Offs

Reliability vs. cost of execution

Example: Java demands all references to array elements be checked for proper indexing, which leads to increased execution costs

Readability vs. writability

Example: APL provides many powerful operators (and a large number of new symbols), allowing complex computations to be written in a compact program but at the cost of poor readability

Writability (flexibility) vs. reliability

Example: C++ pointers are powerful and very flexible but are unreliable

Implementation Methods

Compilation

Programs are translated into machine language

Pure Interpretation

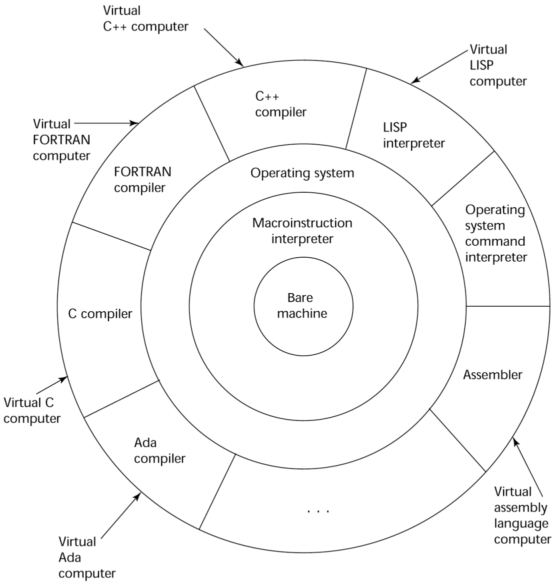
Programs are interpreted by another program known as an interpreter

Hybrid Implementation Systems

A compromise between compilers and pure interpreters

Layered View of Computer

The operating system and language implementation are layered over machine interface of a computer



Compilation

Translate high-level program (source language) into machine code (machine language)

Slow translation, fast execution

Compilation process has several phases:

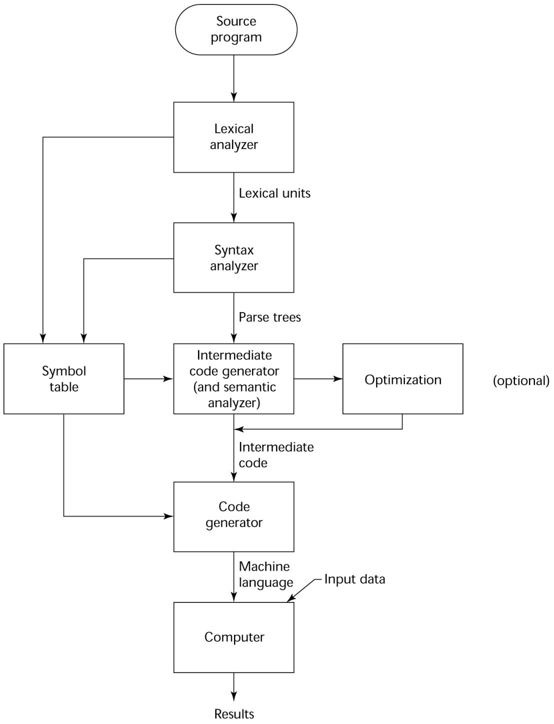
lexical analysis: converts characters in the source program into lexical units

syntax analysis: transforms lexical units into *parse trees* which represent the syntactic structure of program

Semantics analysis: generate intermediate code

code generation: machine code is generated

The Compilation Process



Additional Compilation Terminologies

Load module (executable image): the user and system code together

Linking and loading: the process of collecting system program units and linking them to a user program

Von Neumann Bottleneck

Connection speed between a computer's memory and its processor determines the speed of a computer

Program instructions often can be executed much faster than the speed of the connection; the connection speed thus results in a *bottleneck*

Known as the *von Neumann bottleneck*; it is the primary limiting factor in the speed of computers

Pure Interpretation

No translation

Easier implementation of programs (run-time errors can easily and immediately be displayed)

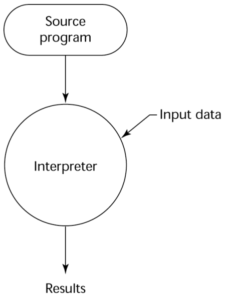
Slower execution (10 to 100 times slower than compiled programs)

Often requires more space

Now rare for traditional high-level languages

Significant comeback with some Web scripting languages (e.g., JavaScript, PHP)

Pure Interpretation Process



Hybrid Implementation Systems

A compromise between compilers and pure interpreters

A high-level language program is translated to an intermediate language that allows easy interpretation

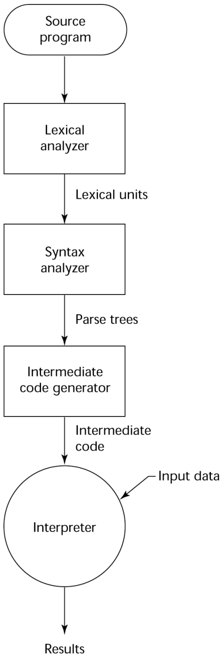
Faster than pure interpretation

Examples

Perl programs are partially compiled to detect errors before interpretation

Initial implementations of Java were hybrid; the intermediate form, *byte code*, provides portability to any machine that has a byte code interpreter and a run-time system (together, these are called *Java Virtual Machine*)

Hybrid Implementation Process



Just-in-Time Implementation Systems

Initially translate programs to an intermediate language

Then compile the intermediate language of the subprograms into machine code when they are called

Machine code version is kept for subsequent calls

JIT systems are widely used for Java programs

.NET languages are implemented with a JIT system

Preprocessors

Preprocessor macros (instructions) are commonly used to specify that code from another file is to be included

A preprocessor processes a program immediately before the program is compiled to expand embedded preprocessor macros

A well-known example: C preprocessor

expands `#include, #define`, and similar macros

Programming Environments

A collection of tools used in software development

UNIX

An older operating system and tool collection

Nowadays often used through a GUI (e.g., CDE, KDE, or GNOME) that runs on top of UNIX

Microsoft Visual Studio.NET

A large, complex visual environment

Used to build Web applications and non-Web applications in any .NET language

NetBeans

Related to Visual Studio .NET, except for Web applications in Java

Summary

The study of programming languages is valuable for a number of reasons:

Increase our capacity to use different constructs

Enable us to choose languages more intelligently

Makes learning new languages easier

Most important criteria for evaluating programming languages include:

Readability, writability, reliability, cost

Major influences on language design have been machine architecture and software development methodologies

The major methods of implementing programming languages are: compilation, pure interpretation, and hybrid implementation