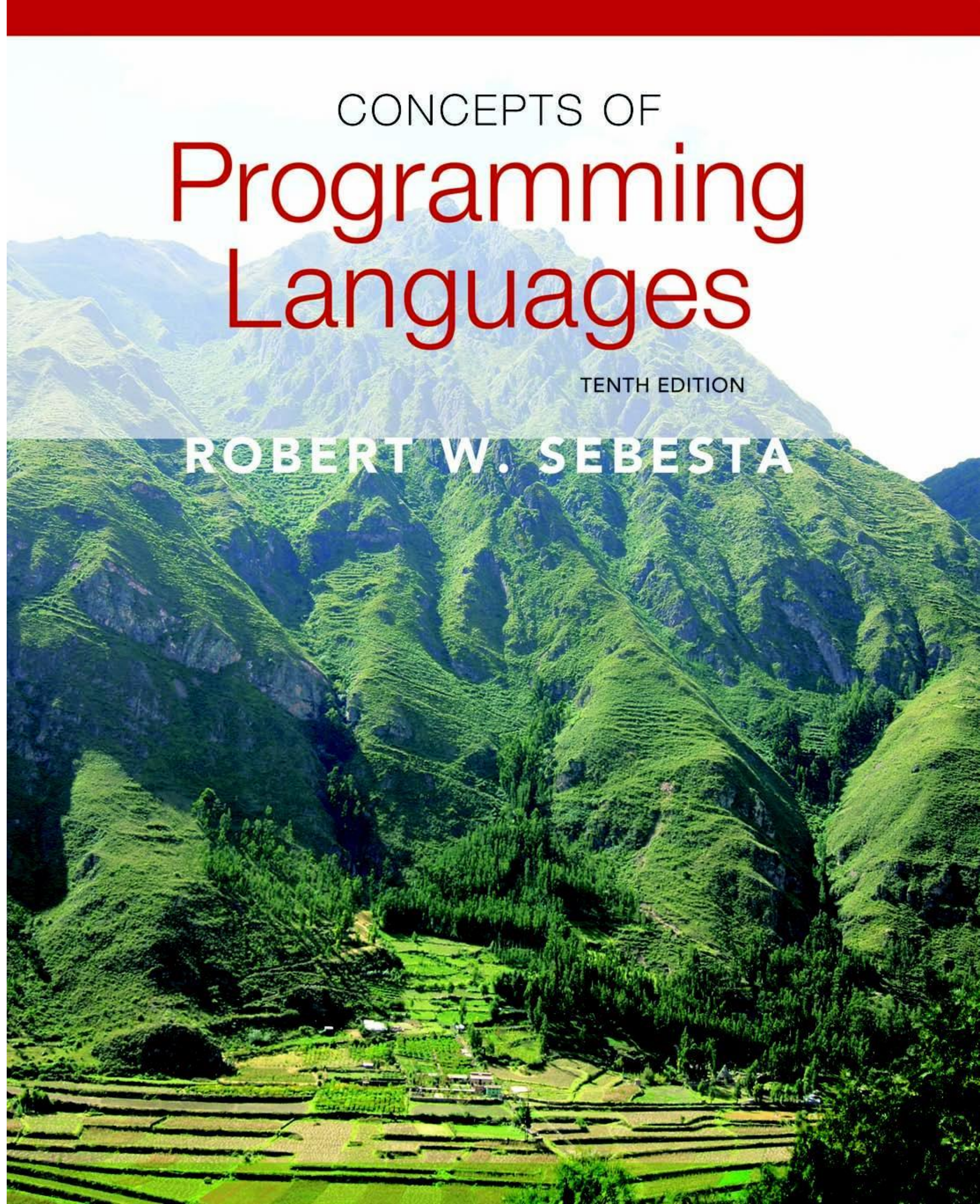
Chapter 1

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
  - the most common general approaches to implementation
  - compilation, interpretation, hybrid implementation systems, preprocessors
- Programming Environments

Reasons for Studying Concepts of Programming Languages

- Increased ability to express ideas (associative arrays in Perl, simulate them in c)
- Improved background for choosing appropriate languages
- Increased ability to learn new languages (Object Orient Programming concept -> Java)
- Better understanding of significance of implementation (program bugs can be fixed)
- Better use of languages that are already known
- Overall advancement of computing (ALGOL 60 vs Fortran)

Programming Domains
(Computer applications & their associated languages)

- **Scientific applications**
  - Large numbers of floating point computations; use of arrays
  - Fortran
- **Business applications**
  - Produce reports, use decimal numbers and characters
  - COBOL (a management system of bank)
- **Artificial intelligence**
  - Symbols rather than numbers manipulated; use of linked lists
  - LISP
- **Systems programming**
  - Need efficiency because of continuous use (OS & Kernel)
  - C (UNIX is OS implemented by C)
- **Web Software**
  - Eclectic collection of languages: markup (e.g., HTML), scripting (e.g., PHP), general-purpose (e.g., Java)

Language Evaluation Criteria

- **Readability**: the ease with which programs can be read and understood **(ease of maintenance)**
- **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 **(p.29, example)**
  - Minimal operator overloading (적은 연산자)

```c
#include <stdio.h>

int main() {
  int number = 3;

  printf("%d\n", number++);
  printf("%d\n", ++number);
  printf("%d\n", number--);
  printf("%d\n", --number);

  return 0;
}
```

- **Orthogonality**
  - A relatively **small set of primitive constructs** can be combined in a relatively **small number of ways** to build the control and data structures of the language
  - 예제)저급언어(IBM, VAX machine – p.30), 고급언어(C – p.31)
  - Good combination of simplicity and orthogonality (LISP, 함수형 언어)

- **Data types:** Adequate predefined data types (P.32, timeOut = true)

- **Syntax considerations**
  - Identifier forms: flexible composition (length of identifier, mnemonic)
  - 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 **(process & data)**

Abstraction of Process – Subprogram

Abstraction of Data – Binary Tree

- **Expressivity**
  - A set of relatively convenient ways of specifying operations
  - Strength and number of operators and predefined functions

(ex) count = count+1 → count++

while → for (for counting loops)

Evaluation Criteria: Reliability

- **Type checking (ch6)**
  - Testing for type errors (by compiler or during program execution)
  - Run-time type checking is expensive
  - **Compile-type checking** more desirable **(Java)**
- **Exception handling (ch. 14)**
  - Intercept run-time errors & take corrective measures **(C++, Java, C#)**
- **Aliasing (ch.5 & 9)**
  - Presence of **two or more distinct referencing methods** for the **same memory location** (dangerous feature)
  - Other languages **restricts aliasing** to increase their reliability
- **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** (Optimization)
  - Reduction of the code size
  - Increase of execution speed of the code that compilers produce
- **Language implementation system**
  - Availability of free compilers
  - Free compiler/interpreter systems of Java became available
- **Reliability**: poor reliability leads to high costs
- **Maintaining programs**
  - poor readability can make the task extremely challenging

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**
  - Most of the popular languages of the past 50 years are developed around the prevalent computer architecture, known as the *von Neumann* architecture
- **Program Design 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

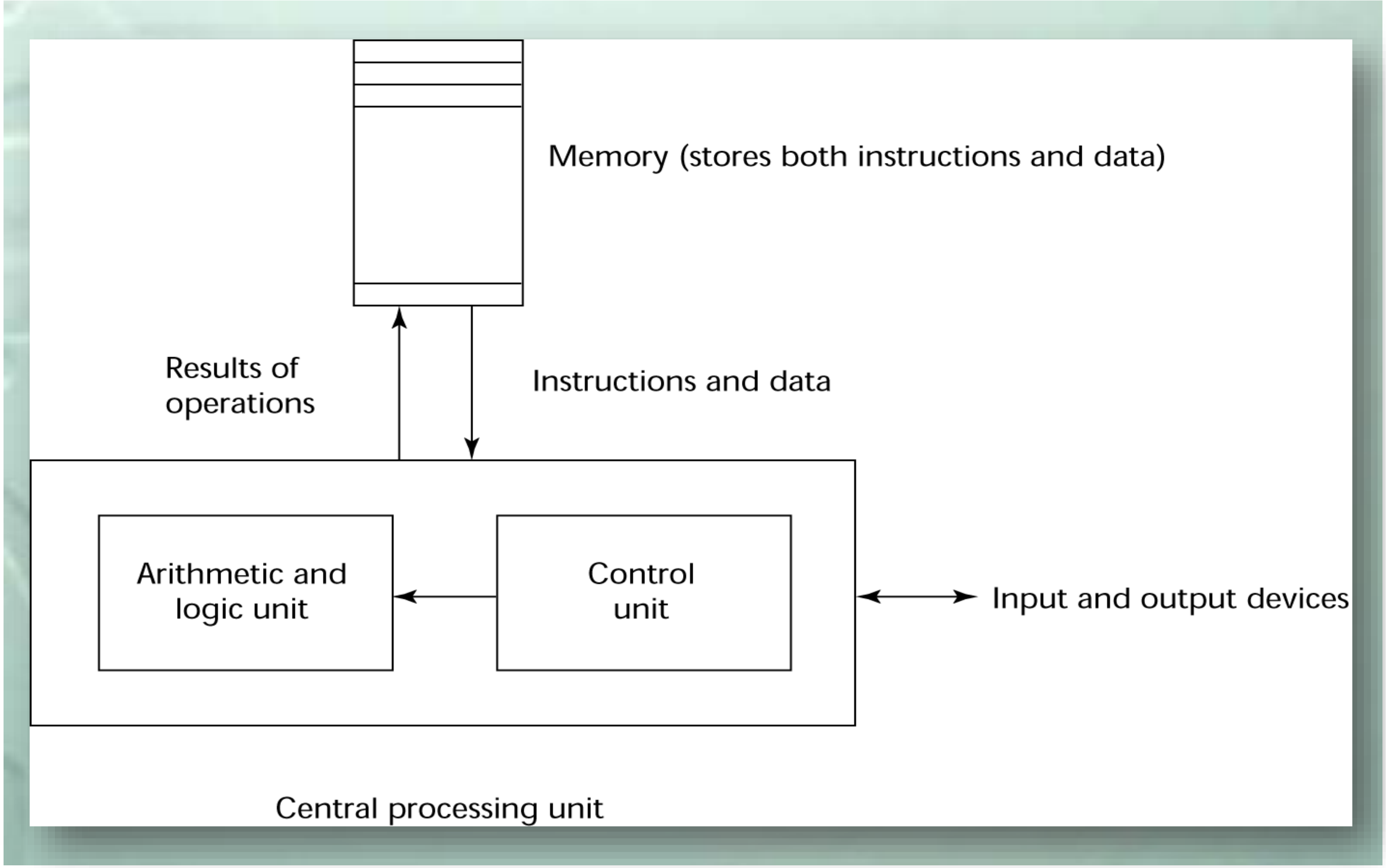
- Well-known computer architecture: **Von Neumann**

- Nearly all digital computers built since 1940s have been based on the von Neumann architecture

- **Imperative(or procedural) languages**, most dominant, because of von Neumann computers
  - Data and programs stored in the same memory
  - CPU, which executes instructions, is separate from memory
  - Instructions and data must be **transmitted**, or **piped**, from memory to CPU

Computer Architecture Influence

- Well-known computer architecture: **Von Neumann**



Computer Architecture Influence

- **The central features of imperative languages**
  - **Variables** model memory cells
  - **Assignment statements** model piping
    - Based on piping operation between CPU and memory cells
  - **Iteration :** the most efficient way to implement repetition on von Neumann architecture
    - Instructions stored in a adjacent cells of memory
    - Repeating the execution of a section of code requires only a branch instruction, which is used to implement IF statements and loops in assembly language

Computer Architecture Influence

- **The central features of imperative languages**

❖ **명령형 언어(imperative language)** 또는 **절차 언어(procedural language)**

✓ 프로그래밍 언어는 컴퓨터의 연산을 모방하고 추상화하는 데서 비롯됨

✓ 따라서 컴퓨터의 구조가 언어 설계에 영향을 미친 것은 당연함

✓ 프로그래밍 언어의 특징

- **명령의 순차적 실행**
- **기억 장소 위치를 표현하는 변수의 사용**
- **변수의 값을 변경하기 위한 배정문(assignment statement)의 사용**

Machine Cycle

- 기계 주기(Machine Cycle)
  - CPU는 하나의 명령어를 실행하기 위해 **인출, 해독, 실행**의 세 과정을 거침
  - **인출(Fetch)**
    - 제어 장치가 **프로그램 카운터**(**PC**)에 있는 주소로 다음 수행할 명령어를 명령 레지스터(**IR**)에 저장
    - 다음 명령어를 수행하기 위해서 **PC**를 하나 증가 시킴
  - **해독(Decode)**
    - 제어 장치는 명령 레지스터(**IR**)에 있는 명령어를 **연산 부분(operation part)**과 **피연산 부분(operand part)**으로 해독
    - 만일 명령어가 피연산 부분이 있는 명령어라면 피연산 부분의 메모리 주소를 **주소 레지스터(AR)**에 저장
  - **실행(Execution)**
    - 중앙처리장치는 각 구성 요소에게 작업 지시를 내림
    - 하나의 명령어 실행이 종료되면 프로그램 카운터가 가리키는 다음 명령어를 가지고 다시 기계 주기를 반복

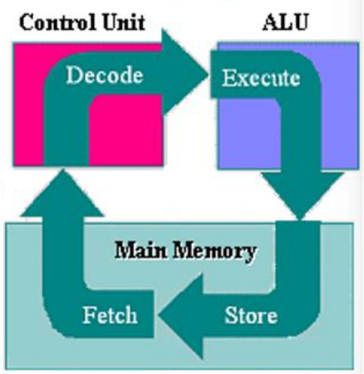


그림 4.23 명령어 실행 과정인 기계 주기

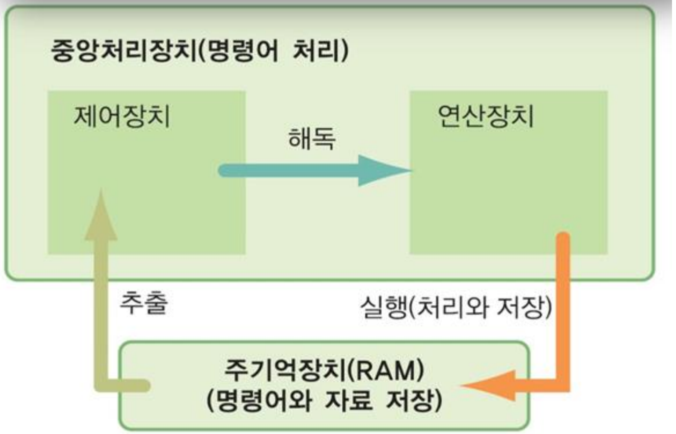


그림 4.24 기계 주기와 자료의 이동

The von Neumann Architecture

- The execution of a machine code program on a von Neumann architecture computer occurs in a process called the **fetch-execute cycle**

Algorithm

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

※ The address of the next instruction to be executed is maintained in a register called **the program counter**

Programming Methodologies Influences

- 1950s and early 1960s: Simple applications; worry about machine efficiency
- Late 1960s: People efficiency became important; readability, better control structures
  (caused by computing costs: HW → SW)
  - structured programming for large and complex tasks
  - top-down design and step-wise refinement
    - Requiring the extensive use of **goto**s
- Late 1970s: Process-oriented to data-oriented
  - **data abstraction**
- Middle 1980s: Object-oriented programming
  - Data abstraction + inheritance + polymorphism

Language Categories (more details in chapter 2)

- **Imperative**
  - Central features are variables, assignment statements, and iteration (ex. these features, both in C and Java, are used in the almost same way)
  - 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, ML, F#
- **Logic**
  - Rule-based (rules are specified in no particular order)
  - Example: Prolog (chapter 16)
- **Markup/programming hybrid**
  - Markup languages extended to support some programming
  - Examples: JSTL, XSLT (extension version of HTML and XML)

Language Design Trade-Offs

- Language evaluation criteria provides a framework for language design
  - **Reliability** vs. **cost of execution**
    - **Example:** Java demands all references to array elements be checked for proper indexing, which leads to increased execution costs (**C language : no index range checking, more faster execution)**
  - **Readability** vs. **writability**
    - **Example:** APL(A Programming Language) 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 (**Not included in Java**)

Language Design Trade–Offs

- No range index checking in C language

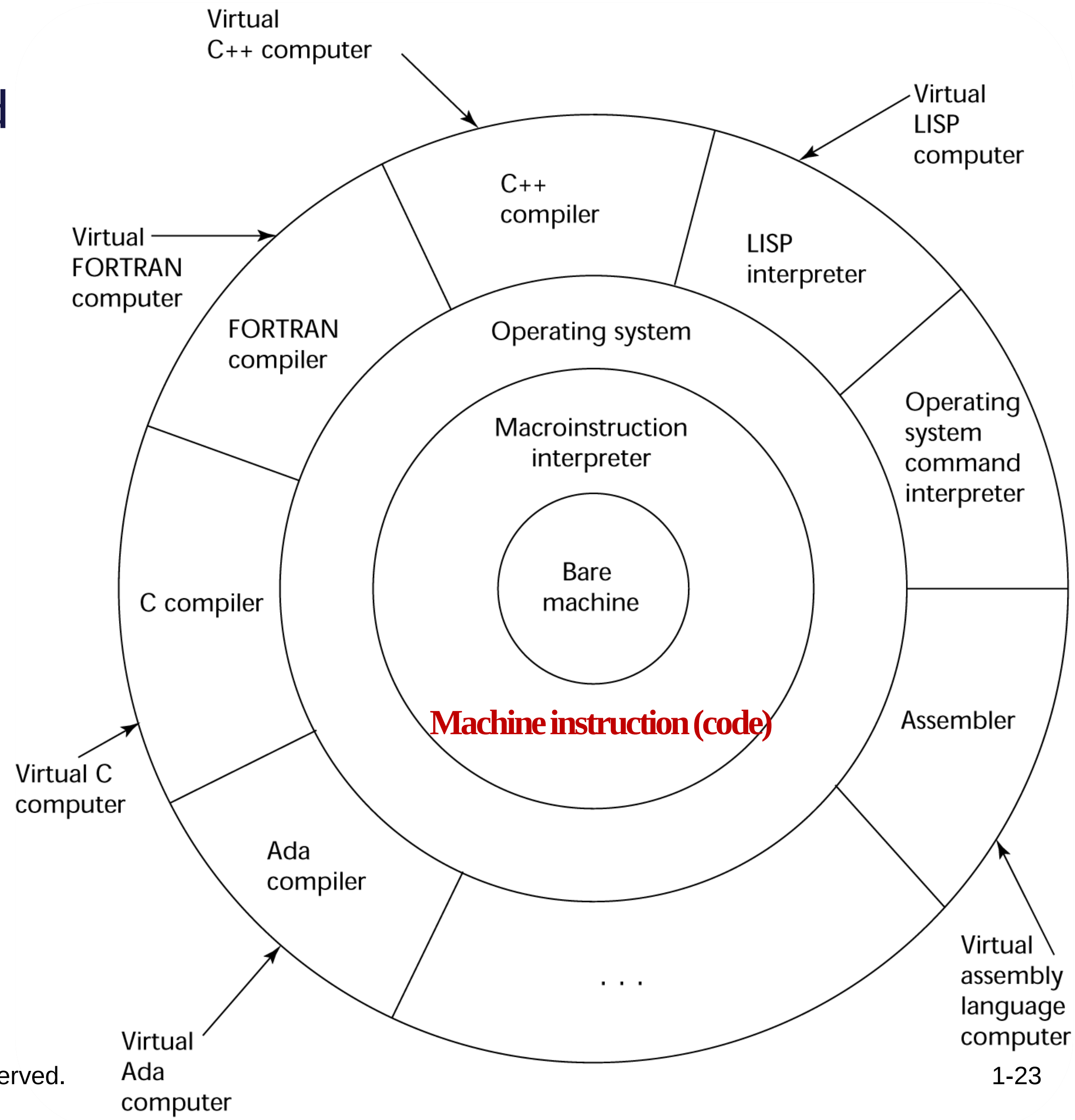
```
#include <stdio.h>
int main()
{
   char hello[12] = “No index range checking! Segmentation fault??";
   int i = 0;
   printf("%s", hello[i]);
   printf("bye bye\n");
}
```

Implementation Methods

- **The primary components of a computer**
  - **Internal memory** : storing programs and data
  - **Processor** : collection of circuits that provides a realization of machine instructions
- **Operating System**
  - Supplies **higher-level primitives** than those of the machine language
    - System resource management, I/O operations
    - File management system, Text / program editors
    - A variety of other commonly needed functions
- **Language implementation systems**
  - Need many of the OS facilities (Managing Memory, controlling I/O, handling Interruptions, securing Data, Processing, such as copy and paste etc.)
  - Interface with the OS rather than directly with the processor (in machine language)

Layered View of a Computer

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



Implementation Methods

- **Compilation (compiler implementation)**
  - Programs are translated into machine language; includes JIT systems
  - Use: Large commercial applications (C, C++, COBOL, Ada)

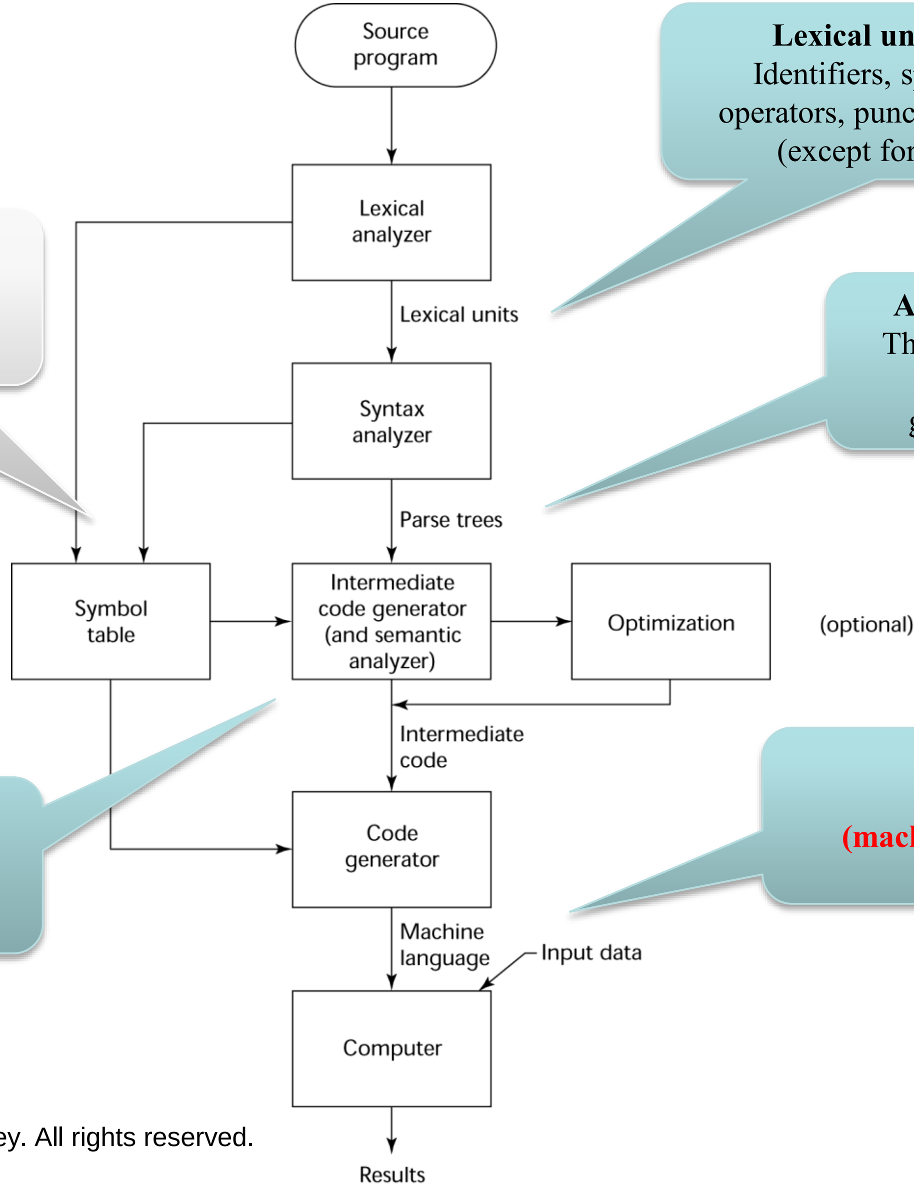
- **Pure Interpretation**
  - Programs are interpreted by another program known as **an interpreter**
  - Use: Small programs or when efficiency is not an issue

- **Hybrid Implementation Systems**
  - A compromise between compilers and pure interpreters
  - Use: Small and medium systems when efficiency is not the first concern

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 (**tokens**)
  - Syntax analysis: transforms lexical units into ***parse trees*** which represent the syntactic structure of program
  - Semantics analysis: generate intermediate code (**type checking**)
  - Code generation: machine code is generated (**target machine dependent**)

The Compilation Process



Lexical units (tokens)
Identifiers, special words, operators, punctuation symbols (except for **comment**)

Symbol table
The **type and attribute** information of each user-defined name in the program

Abstract Syntax Tree (AST)
The **information** that would be required to build **a tree** is generated and used directly

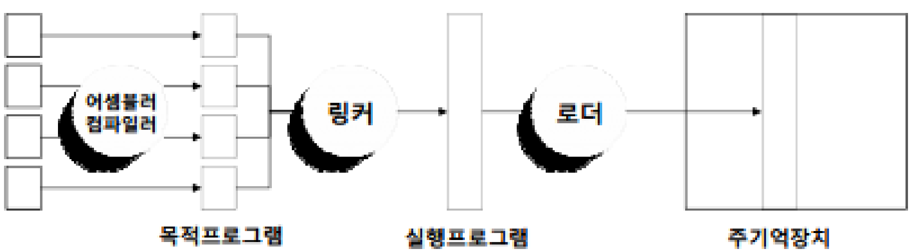
Semantic analyzer
Semantic checking
(type error checking)

Code generator
(machine-dependent part)

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

- 링킹(linking), 링커(linker)
  - 여러 개의 목적 프로그램을 연결하여 하나의 실행 가능한 프로그램을 만드는 과정
- 로더(loader)
  - 프로그램의 실행을 위하여 메모리에 적재



Von Neumann Bottleneck

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

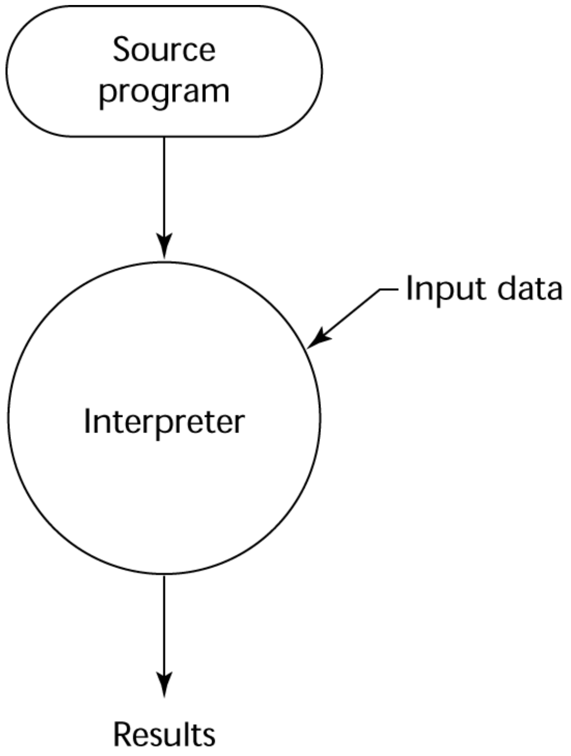
- Program instructions often can be executed much faster than the speed of the connection; the <u>connection speed</u> thus results in a *bottleneck*

- Known as the *von Neumann bottleneck*; it is the primary limiting factor in the speed of computers
  - **One of the primary motivations** for the research and development of **parallel computers**

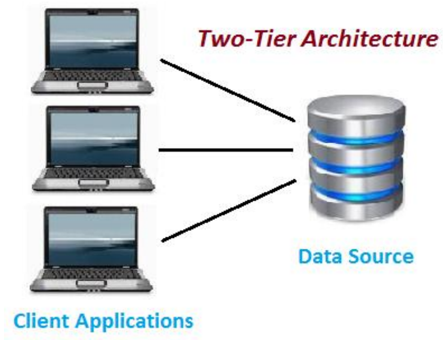
Pure Interpretation

- 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
  - **Statement decoding** is the bottlenect
- Often requires more space
  - Source program & symbol table **during interpretation**
- Early languages of the 1960s(APL, SNOBOL, and LISP)
  (Now rarely used on high-level languages)
- Significant comeback with some Web scripting languages (e.g., JavaScript, PHP, JSP, ASP)

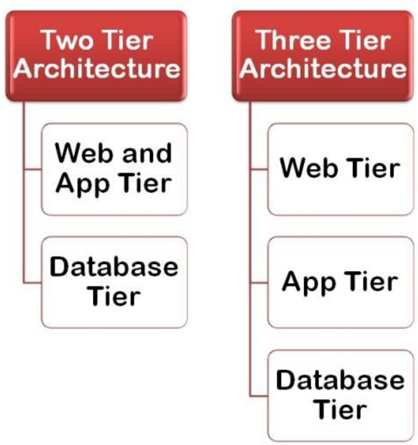
Pure Interpretation Process

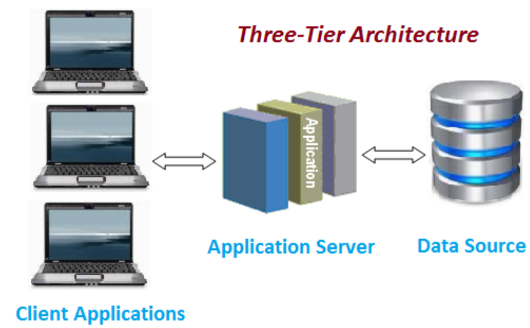


Two–Tier and Three–Tier Architecture



- Client-server architectured
- Direct communication
- Run faster(tight coupled)



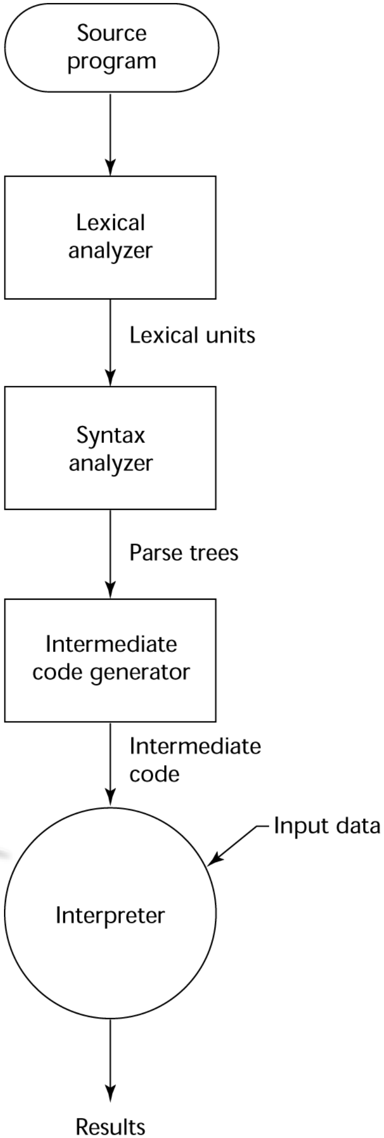


- Client-server architectured
- Performance
  (Presentation tier can cashe requests
  newtork utilization is minimized, and
  the load is reduced on the application and data tiers)
- Scalability
  (Each tier can scale horizontally)
- Better Re-use
- High degree of flexibility in deployment platform and conficuration
- Improved Security and Integrity
- Easy to maintain and modification is bit easy, won't affect to other modules

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



Example - Java
JVM (Java Virtual Machine)
Interpreter and run-time system

Just-in-Time Implementation Systems

- Initially translate programs to an intermediate language
- Then, during execution, JIT compiles the intermediate language methods into machine code when they are called
- Machine code version is <u>kept for subsequent calls</u>
- *JVM, .NET, V8(javascript engine, node.js) supports JIT*

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 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


THANK
YOU

