National University
Of Computer and Emerging Sciences

Theory of Programming Languages

Course Structure

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Pre-requisite (Recommended)

- Theory of Automata
- Compiler Construction

Recommended Textbook

- Concepts of Programming Languages by Robert W. Sebesta

Evaluation Plan

Evaluation Type	Points
Quiz	10
Mid-I	15
Mid-II	10
Final	35
Assignments/Presentations	10
Class Participation	05
Project/Term Paper	15

Class Guidelines

- ***Please don't miss a class.***
- Please don't use ***mobile phones*** in the class.
- Plagiarism in Assignments/case studies is ***not allowed***.
- ***No Makeup Quiz OR Assignments will be given.***
- Final exam will be selective comprehensive.
- At least ***50% Marks*** are required to pass this course.

Course Outline

- Programming Languages Fundamentals
- Evolution of Different Languages
- Syntax and semantics
- Lexical analysis
- Concept of main programming constructs
- Primitive Datatypes
- Arithmetic expressions
- Selection, iterative statements
- Fundamentals of subprograms
- Fundamentals of abstraction
- Object oriented pregaming
- Functional programming
- Logic programming

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Programming Languages Fundamentals

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Best Programming
Languages for Web Development
PHP
HTML5
.com
HTML5
JAVA
http:
Swift
http:
JS
Python
C#
Ardulno
Ruby
CSS3
Swift

Why TPL?

- 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., HTML), 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

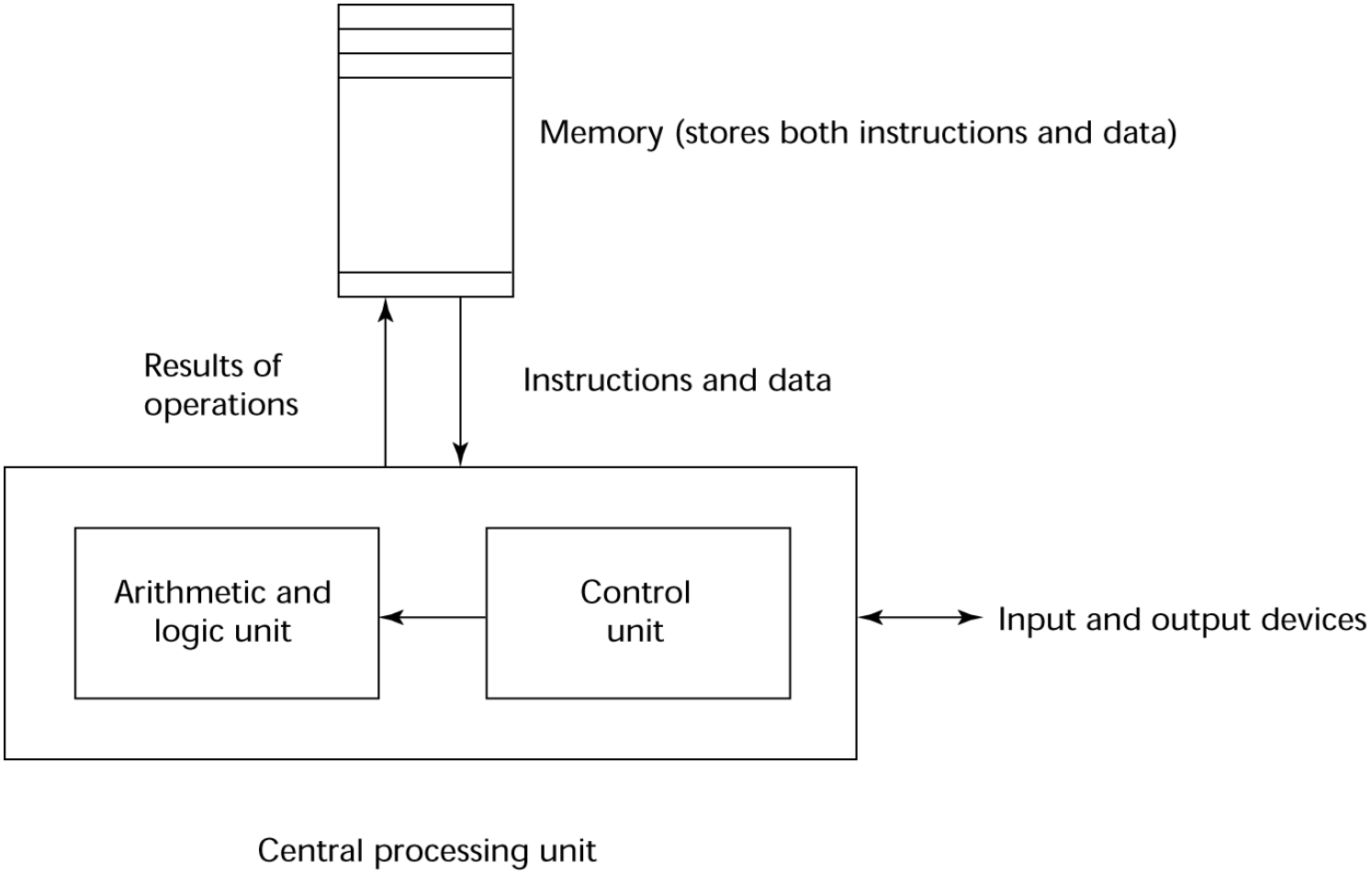
- Computer Architecture
  - » Languages are developed around the prevalent computer architecture, known as the *von Neumann* architecture

- 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
- 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

The von Neumann Architecture



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 and 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#

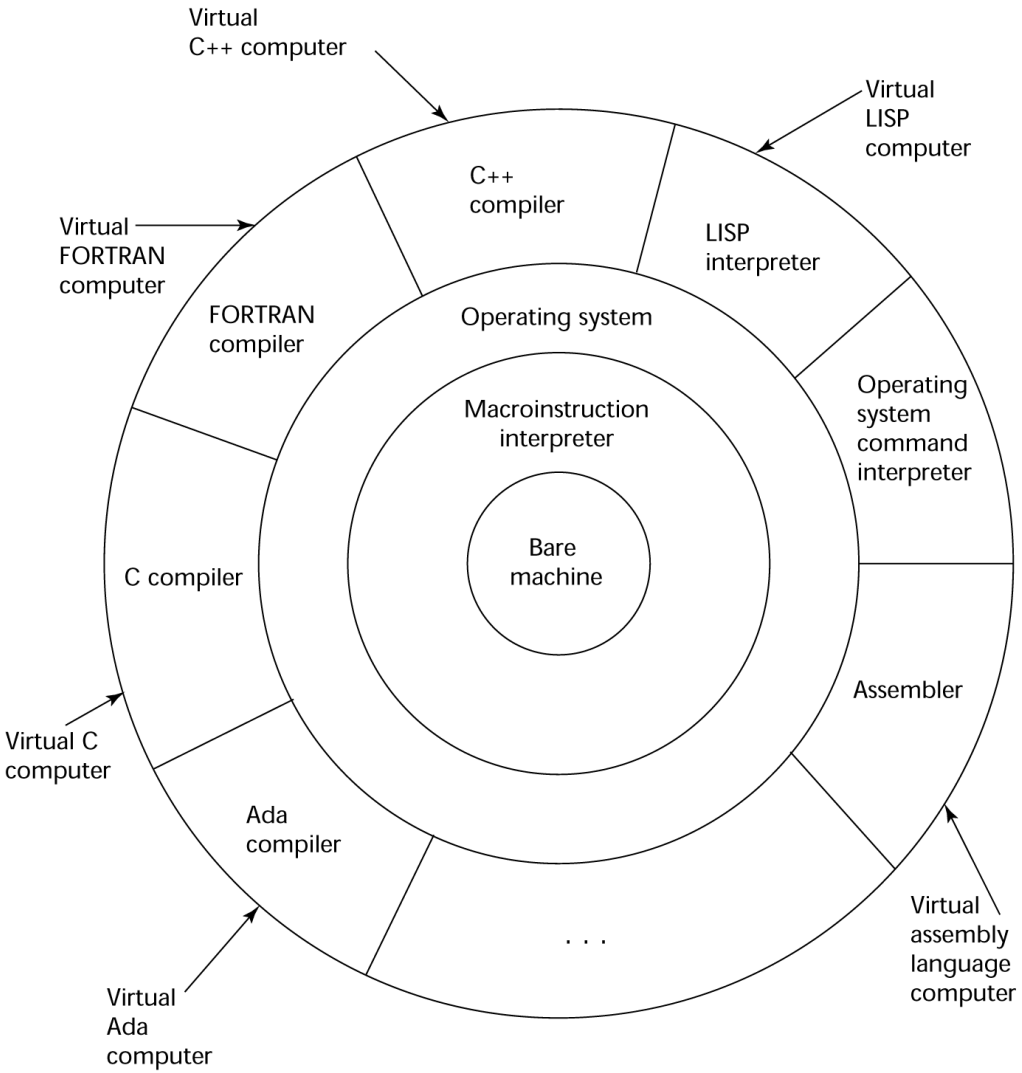
- Logic
  - » Rule-based (rules are specified in no particular order)
  - » Example: Prolog

- 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

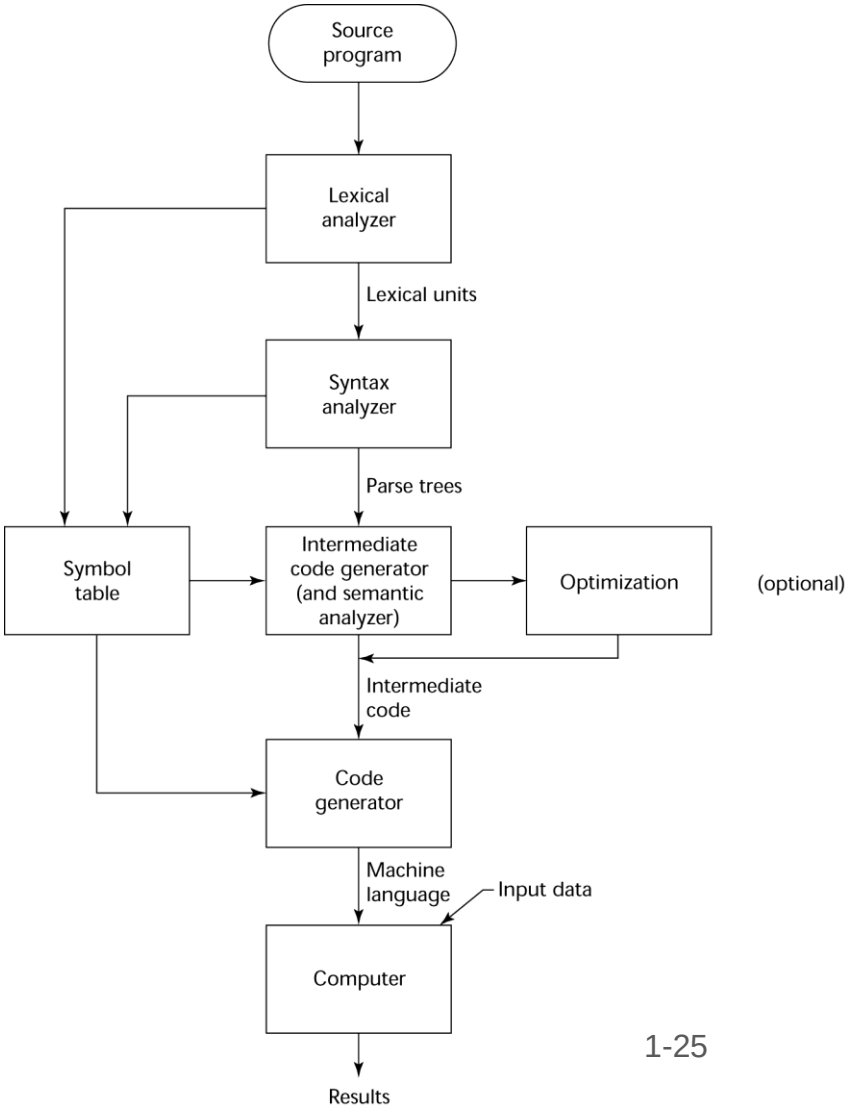
Implementation Methods – Layered View of Computer



Implementation Methods -- 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

Implementation Methods -- Compilation



Implementation Methods -- Compilation

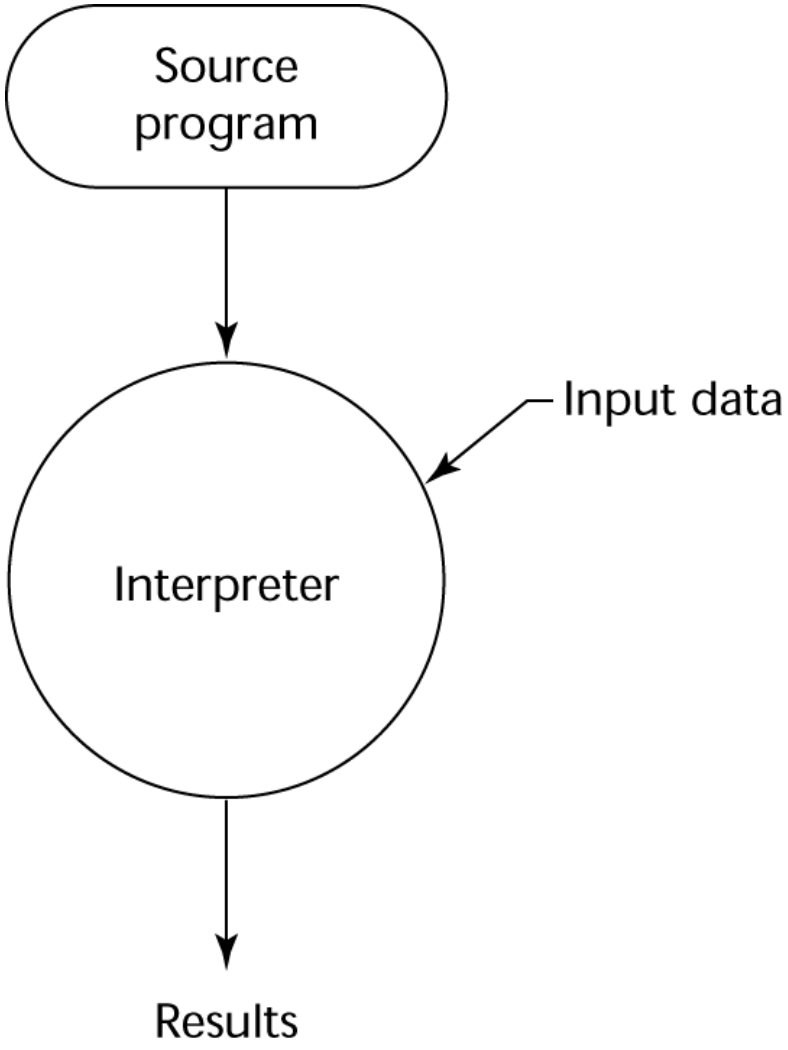
- **Load module** (executable image): the user and system code together
- **Linking and loading:** the process of collecting system program units and linking them to a user program

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

Implementation Methods -- 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), *why?*
- Often requires more space
- Now rare for traditional high-level languages
- Significant comeback with some Web scripting languages (e.g., JavaScript, PHP)

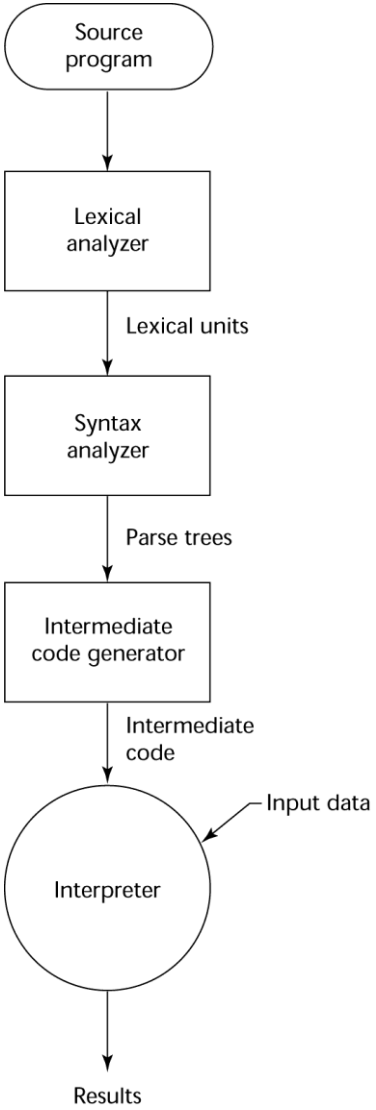
Implementation Methods -- Pure Interpretation Process



Implementation Methods -- 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*)

Implementation Methods -- Hybrid Implementation Process



Implementation Methods -- 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
- In essence, JIT systems are *delayed compilers*

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