PR2 - Programming 2

Lecture 1

Overview of Programming Languages

Outline

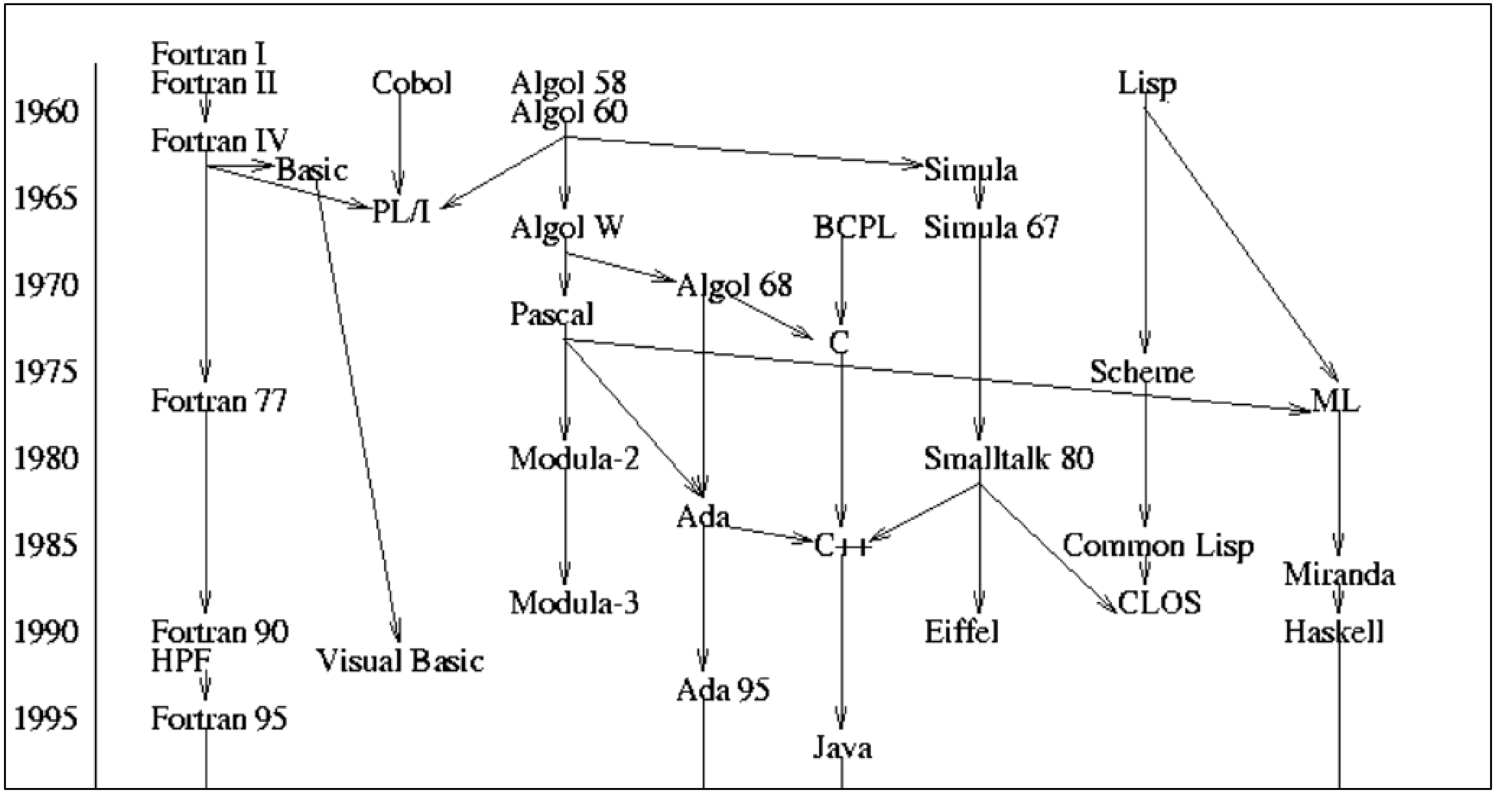
- History of Programming language
- PL features
- What makes a good PL?
- Why study PLs?

References

- Michael L.Scott, **Programming Language pragmatic**, chapter 1
- Robert W. Sebesta, **Concept of Programming Languages**, chapter 1
- Le Minh Duc, **Object Oriented Program Development**, chapter 1

History of Programming language

- Thousands of Programming languages have been created



What is a Programming Language?

- Fortran
- Java
- C/C++
- Lisp
- JS
- HTML
- Kotlin
- Cobol
- PHP
- Algol 60
- Basic
- C#
- Pascal,…

Why so many PLs?

- **Evolution:** constantly finding better ways to do things
  - 1960-70: goto-based languages (Fortran, Cobol, Basic) → loops, case (switch) statements (higher level constructs)
  - late 1980s: nested block structure languages (Algol, Pascal, and Ada) → object-oriented languages (Smalltalk, C++, Eiffel, etc.)
- **Special purposes:**
  - designed for solving specific problem domain(s)
- **Personal preference:**
  - different programmers like different things

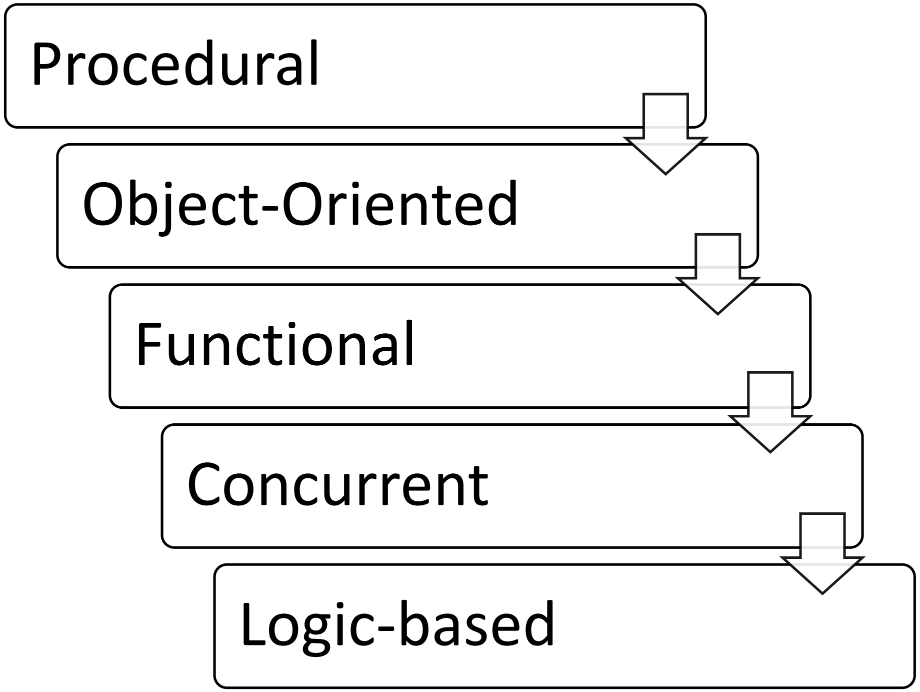
Programming Domains

- Scientific Applications:
  - Fortran, ALGOL 60, …
- Business Applications:
  - COBOL
- Artificial Intelligence:
  - Lisp, Prolog, …
- Web Software:
  - HTML, Js, Php, …

What makes languages evolve?

- Changes in hardware or implementation platform
- Changes in attitudes to safety and risk
- New ideas from academic or industry

Evolution of Programming Paradigms



Procedural

Object-Oriented

Functional

Concurrent

Logic-based

- Paradigm shifts are driven by hardware, industry, and academia

Classification of Programming Languages

- **Declarative language**
  - A type of programming that specifies what to do.
  - E.g. SQL statements such as “select * from table” tell a program to get information from a database, but not how to do so
- **Imperative language**
  - A type of programming that specifies how to do.
  - E.g. when we want to calculate “triple x”, imperatively we would have “x = x*3” or “x = x+x+x”

Declarative language vs Imperative language

Declarative programming is like describing your problem to a mathematician. Imperative programming is like giving instructions to an idiot.

Functional Programming Languages

- Focus on immutability and pure functions
- Examples:
  - Haskell
  - Scala
  - F#
- Benefits
  - easier reasoning
  - fewer side effects
  - strong support for parallelism
- Growing relevance in data science and distributed systems

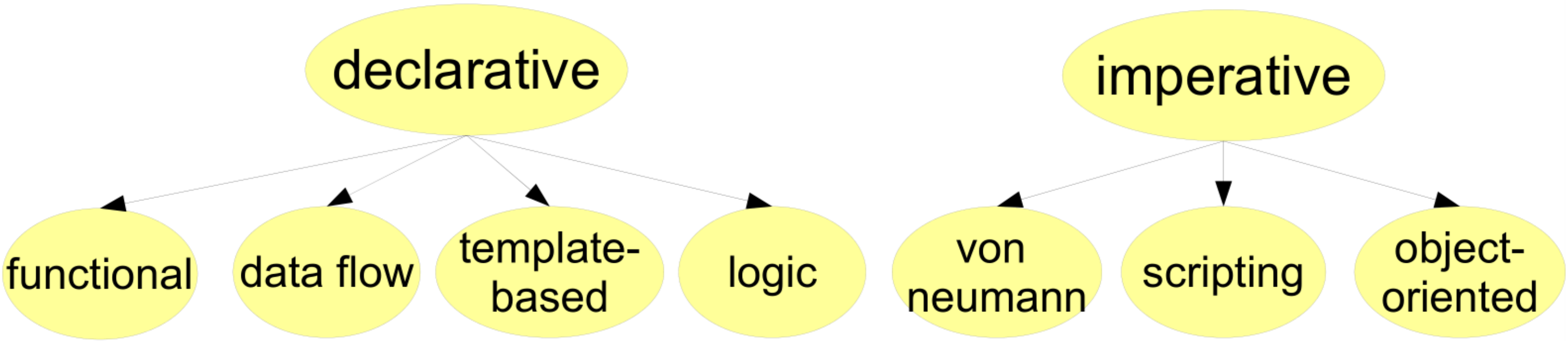
Logic Programming Languages

- Based on formal logic and inference
- Example: Prolog
- Used in AI, knowledge representation, and expert systems
- Programs are sets of facts and rules, execution is query resolution

Scripting Languages

- Designed for automation and rapid prototyping
- Examples: Python, JavaScript, Perl, Ruby
- Strengths:
  - ease of use
  - fast development cycles
  - large ecosystems
- Common in web development, data analysis, and DevOps

PL detail classification



declarative

imperative

functional

data flow

template-based

logic

von neumann

scripting

object-oriented

Lisp/Scheme
ML
Haskell

Id,
Val

XSLT

Prolog,
spreadsheet

C,
Ada,
Fortran

Perl,
Python,
PHP

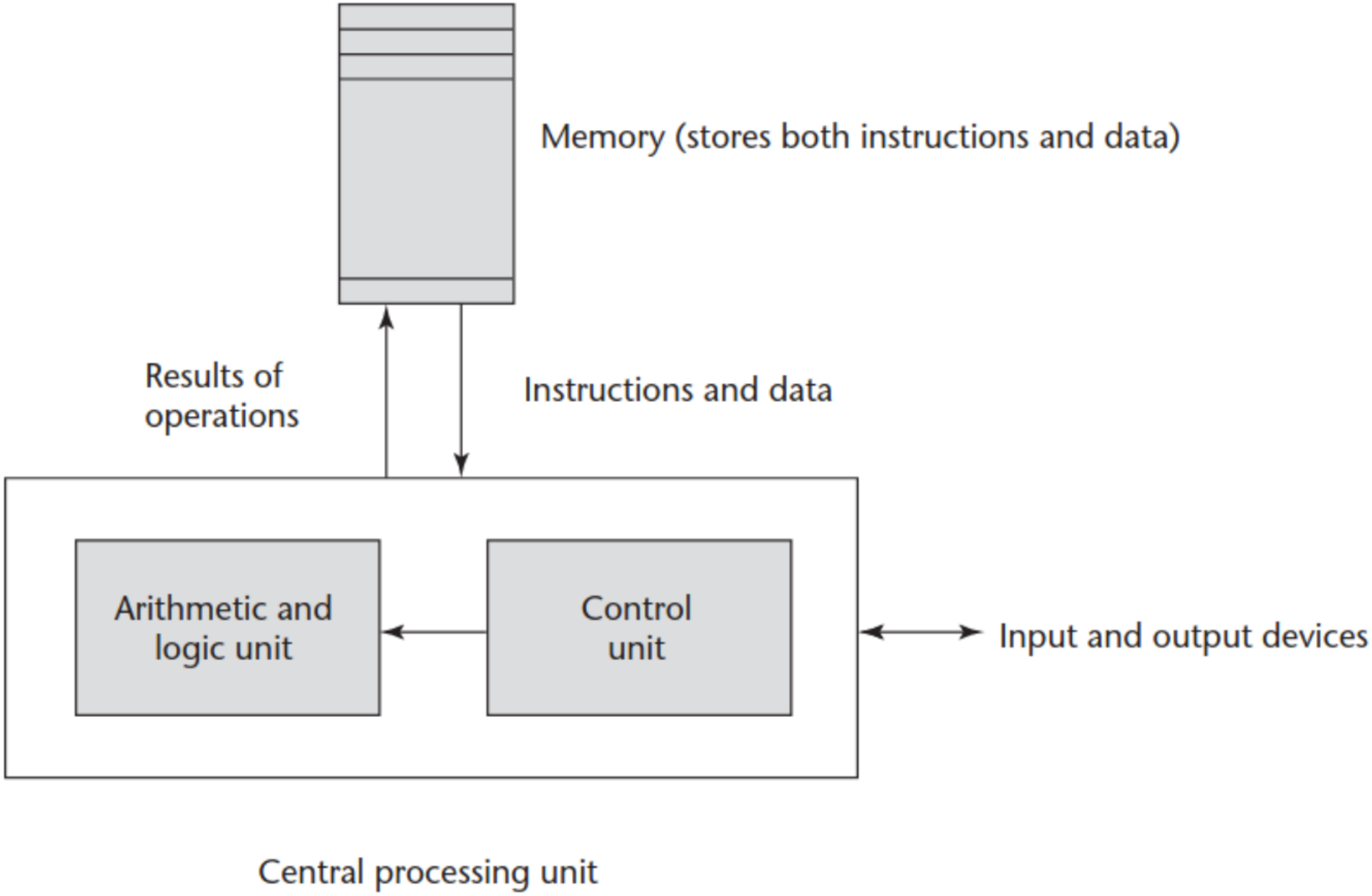
Smalltalk,
Eiffel,
Java

based on model of computation

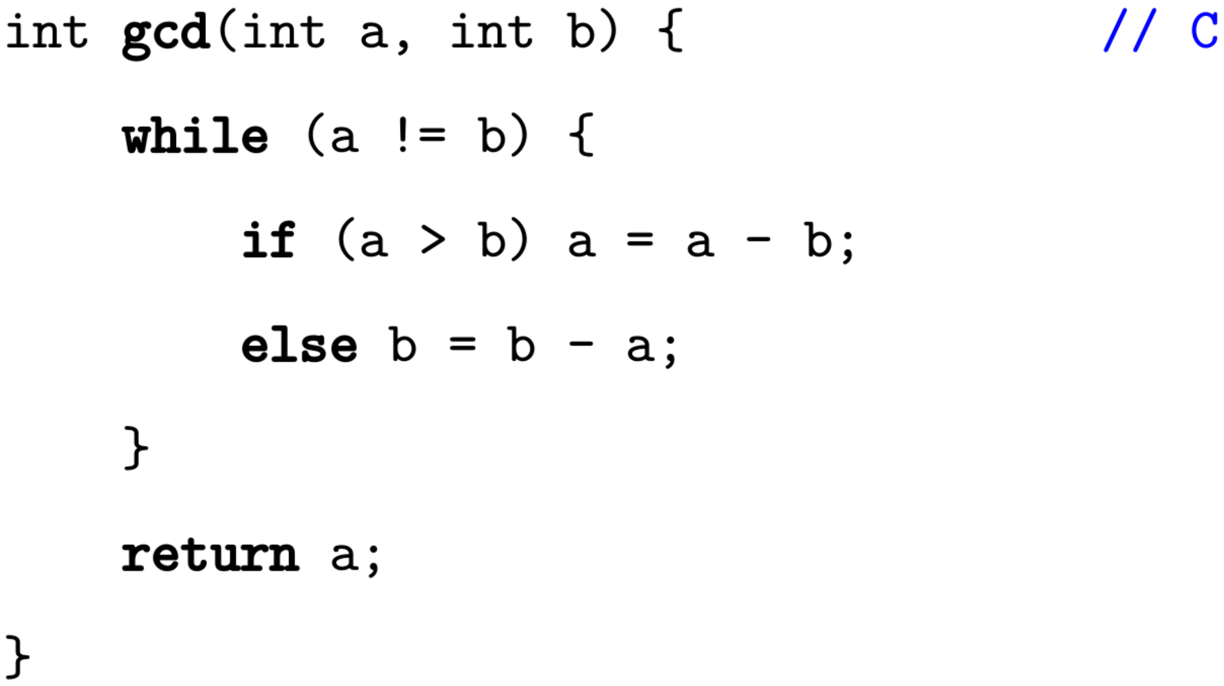
Von Neumann PLs

- The (once) most successful PL type:
  - Past: Fortran, Ada 83, C
  - Present: Java, Python, JavaScript
- Important subtypes
  - Scripting PL (e.g. TypeScript/Javascript): high-level expressions over a library of components
  - OOPL (e.g. Java, C#): objects and their interactions
- Based on the Von Neumann computer architecture:
  - data (run-time memory) + processing (CPU)
- Declaration and modification of variables

von Neumann computer architecture

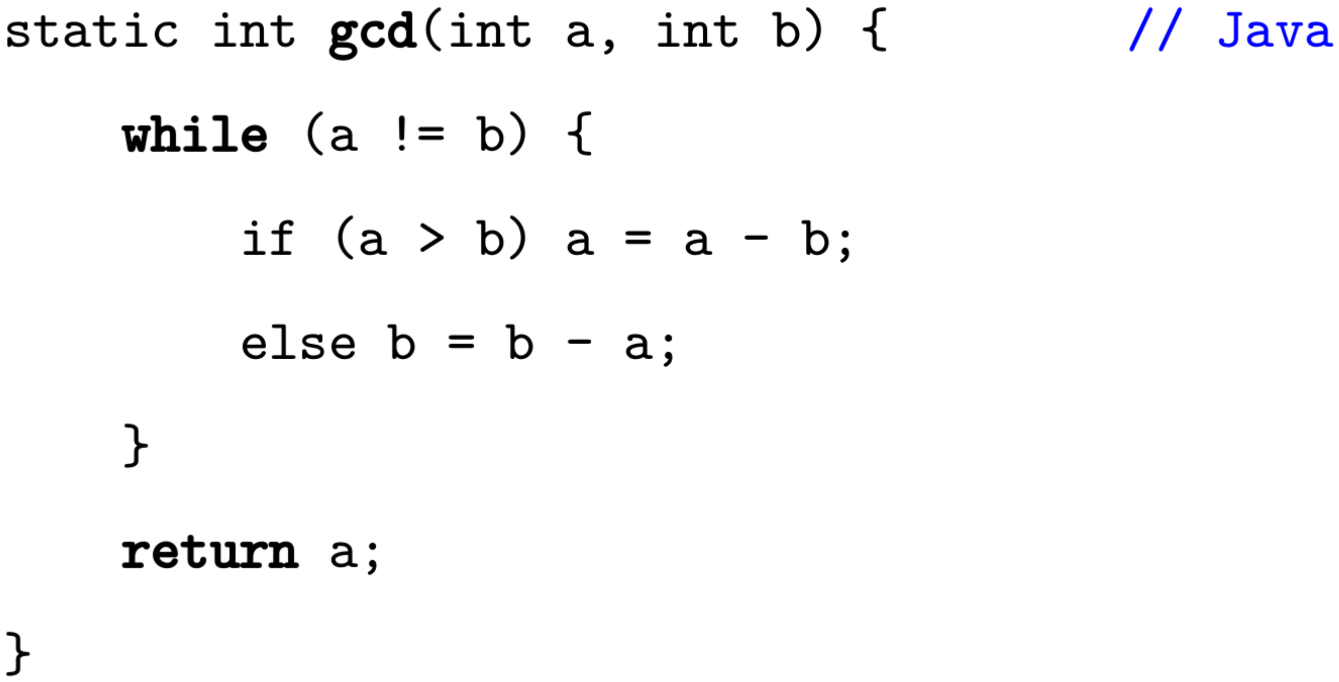


Example: Gcd in C



```
int gcd(int a, int b) {                    // C
    while (a != b) {
        if (a > b) a = a - b;
        else b = b - a;
    }
    return a;
}
```

Example: Gcd in Java



```
static int gcd(int a, int b) {          // Java
    while (a != b) {
        if (a > b) a = a - b;
        else b = b - a;
    }
    return a;
}
```

What did the examples tell us?

- Source code written in imperative languages often looks similar.
  - Once you have mastered one imperative language, it is relatively easy to learn another.
  - However, transitioning to a declarative language can be more challenging, even after gaining experience with imperative languages.
  - This difficulty arises because different programming paradigms demand distinct ways of thinking and problem-solving.

Language Design Trade-offs

- Performance vs. Safety
  - C vs. Java
- Ease of learning vs. Expressive power
  - Python vs. Haskell
- Portability vs. Hardware optimization
  - Java vs. C++
- No language is perfect; each balances trade-offs differently

Programming Language Implementation

- **Compiler:** translates source code into machine code (C, C++)
- **Interpreter:** executes code directly (Python, Ruby)
- **Hybrid approaches:** Java (bytecode + JVM), JavaScript (**J**ust-**I**n-**T**ime compilation)
- Implementation affects performance, portability, and debugging

PL features

A PL can be assessed in the following aspects

- Expressive power
  - Write clear, concise & maintainable code
  - Abstraction
- Ease of use
  - Low learning curve for beginning programmers
- Ease of implementation
  - Suitable for average machines
  - Accessible (e.g. free for educational use)

PL features (cont’d)

- Standardization
  - following standards
  - ensure the portability of code across platforms
- Open source
  - at least one open-source compiler / interpreter of the language
- Excellent compilers
  - fast code generation
  - other support tools to help manage large projects

PL features (cont’d)

- Economics, Patronage, and Inertia
  - backing of powerful sponsor(s)/communities
  - e.g. C# backed by Microsoft, Java backed by Sun/Oracle
  - Python, PHP, JavaScript, Node.js... backed by communities

A PL is a compromise...

- Between the desires of programmer and PL implementer
- Programmer: PL user
  - language = means of expressing algorithms
  - main concern: conceptual clarity
- PL implementer: PL designer/creator
  - language = means of instructing computers
  - main concern: implementation efficiency
- To achieve both concerns require making compromises!

Modern Trends in Programming Languages

- Multi-paradigm languages
  - e.g., Python, Scala, Rust
- Domain-specific languages (DSLs)
  - for finance, graphics, data pipelines
- Increased focus on concurrency and parallelism
- Stronger type systems for safety
  - Rust, Swift, Kotlin

Why study principles of PLs?

- Know the special features
- Understand different ways of expressing
- **Able to choose a PL for a given task**
- Make it easier to learn new PLs
- Use language tools to speed up development process (debuggers, assemblers, linkers)
- Add new useful features to a language
- Make better use of language technology
  - e.g. to write better programs

Why Study PLs in Depth?

- Understand paradigm shifts and anticipate future trends
- Gain ability to evaluate trade-offs when choosing a language
- Improve adaptability: easier to learn new languages
- Develop deeper appreciation for language design and its impact on software quality

Summary

- Many PLs exist because of *evolution*, *purpose* & *preference*
- PL spectrum includes a categorisation of PLs into *declarative* and *imperative* forms
- A PL strikes a balance between conceptual *clarity* and implementation *efficiency*
- Study PLs help raise the awareness of and choose suitable PL(s) for a given task