CS-3304 Introduction

In Text: Chapter 1 & 2

COURSE DESCRIPTION

What will you learn?

- Survey of programming paradigms, including representative languages
- Language definition and description methods
- Overview of features across all languages
- Implementation strategies

Semester Outline

- Introduction and Language Evaluation
- History and Evolution
- Syntax and Semantics
- Names, Typing, and Scoping
- Expressions and Assignment
- Control Structures
- Subprograms
- Functional Programming
- Logic Programming

Websites

- Course homepage: lecture notes and schedules

http://courses.cs.vt.edu/cs3304/fall17/

- Canvas website: assignments, grades, and announcements

https://canvas.vt.edu/courses/56037

INTRODUCTION TO PROGRAMMING LANGUAGES

Overview

- Why study programming languages?
- What types of programming languages are there?
- What are language implementation methods?
- What is the process of compilation?

WHY STUDY PROGRAMMING LANGUAGES?

Why are there so many PLs?

- Evolution: people have learned better ways of doing things over time
- Socio-economic factors: proprietary interests, commercial advantage
- Orientation towards special purposes
- Orientation towards special hardware
- Diverse ideas about what is pleasant to use

What makes a language successful?

- Expressive power (C, Algol-68, Perl)
  - Easy to express things
  - Although every language is Turing complete, language features have huge impact
  - We will focus on factors contributing to expressive power in the course
- Ease of use (Pascal, Java, Python)
  - Easy to learn

- Ease of implementation (BASIC, Forth)
  - The languages can be implemented/installed on tiny machines
- Standardization (ANSI C)
  - To ensure portability of code cross platforms
- Open source (C)
  - With at least one open-source compiler or interpreter

- Excellent compilers (Fortran, Common Lisp)
  - Possible to compile to very good (fast/ small) code
- Economics, Patronage, and Inertia
  - The backing of a powerful sponsor
  - E.g., COBOL and Ada by DoD, PL/1 by IBM

Why study PLs?

- 1. Make it easier to learn new languages
  - Some languages are similar; easy to walk down family tree
    - E.g., from Java to C#, from Pascal to C

- 2. Simulate useful features in languages that lack them
  - Certain useful features are missing in some languages, but can be emulated by following a deliberate programming style
    - E.g., Older dialects of Fortran lack suitable control structures, so programmers can use comments and self-discipline to write well-structured code

- 3. Choose among alternative ways to express things based on the knowledge of implementation costs/performance overhead
    - Use simple arithmetic equivalents (use x*x instead of x^2)
    - Avoid call by value with large data items in Pascal
    - Manual vs. automatic memory management

- 4. Make better use of language technology whenever it appears
  - The code to parse, analyze, generate, optimize, and otherwise manipulate structured data can be found in almost any sophisticated program
  - Programmers with a strong grasp of the language technology will be able to write better structured and maintainable code

- 5. Get prepared to design new languages or extend existing languages
  - Easy-to-use
  - Easy-to-learn
  - Easy-code-to-maintain
  - … …

A Story: ALGOL 60 vs. Fortran

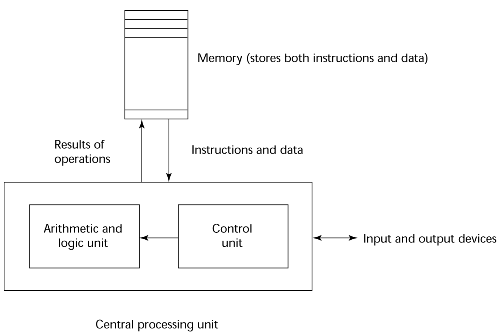
- ALGOL 60 (Backus et al., 1963) was more elegant and had much better control statements than Fortran (McCracken, 1961)
- ALGOL 60 failed to displace Fortran
  - Poor understanding of the new language
  - No appreciation on the benefits of block structures, recursion, and various control structures

OVERVIEW OF PROGRAMMING LANGUAGES

Influences on Language Design

- Computer Architecture
- Programming Design Methodologies

The von Neumann Architecture



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 Design Methodologies

- 1950s and early 1960s
  - Simple applications
  - Worry about machine efficiency and hardware cost

Programming Design Methodologies

- Late 1960s: hardware costs decreased and programmer costs increased
  - Large and complex applications
  - People efficiency became important
  - Readability: better control structures
    - structured programming
    - top-down design and step-wise refinement

Programming Design Methodologies

- Late 1970s: Process-oriented to data-oriented
  - Data abstraction: using abstract data types
- Middle 1980s: Object-oriented programming
  - Data abstraction + inheritance + polymorphism

The PL spectrum

- Declarative
  - Functional Lisp/Scheme, ML, Haskell
  - Dataflow Id, Val
  - Logic, constraint-based Prolog, SQL
- Imperative
  - von Neumann C, Ada, Fortran
  - Object-oriented Smalltalk, Eiffel, Java
  - Scripting Perl, Python, PHP

Declarative vs. Imperative

- "High-level" vs. "Low-level"
- Programmers specify "what should be done" or "steps to do it"
- An example (*C#*): choose all odd numbers in a collection

```
var results =
collection.Where( num => num %
2 != 0);
```

```
List<int> results = new List<int>();
foreach(var num in collection)
{
   if (num % 2 != 0)
        results.Add(num);
}
```


Functional Languages

- Employ a computational model based on recursive definition of functions
- Take inspiration from the lambda calculus
  - A program is considered as a function from inputs to outputs, defined in terms of simpler functions through a process of refinements
- We will talk a lot about these languages

Dataflow Languages

- Model computation as the flow of information (tokens) among primitive functional nodes
- Provide an inherently parallel model:
  - Nodes are triggered by the arrival of input tokens, and can operate concurrently

Logic or Constraint-Based Languages

- Take inspiration from predicate logic
- Model computation as an attempt to find values that satisfy certain specified relationships, using goal-directed search through a list of logical rules

von Neumann Languages

- Most familiar and widely used
- The basic means of computation is the modification of variables

Object-oriented Languages

- Closely related to the von Neumann languages
- Have a much more structured and distributed model of both memory and computation
- Picture computation as interactions among semi-independent objects, each of which has both its own internal state and subroutines to manage that state

Scripting Languages

- Emphasize coordinating or "gluing together" components drawn from some surrounding context
- Support scripts, programs written for a special run-time environment that automate the execution of tasks, which could alternatively be executed one-by-one by a human creator