CONCEPTS OF

PROGRAMMING LANGUAGES

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Introduction, or Why Bother With This Stuff, Anyway?

- Increased capacity to express ideas.
- Improved background for choosing languages.
- Increased ability to learn languages.
- Understanding of significance of implementation.
- Ability to design new languages.
- Overall advancement of computing.
Language Evaluation Criteria

- Readability & Writability

  → Simplicity

  • small # of basic components
    (subsets a poor solution!)
  • one syntax: one meaning

  Counter-example in C: four ways to increment x:
  
  x++;  
  x=x+1;  
  x+=1;  
  ++x;

  In FORTRAN, two meanings for:
  
  Y=SUM(I,J)
  
  -- array reference
  -- function call
Language Evaluation Criteria

→ Orthogonality

=> Any composition of basic primitives is allowed

- need small set of primitives, ways to combine them
- Pascal not very orthogonal.
  Functions can't return structured types.
  Type of formal parameter must be stated in function/procedure heading unless parameter is a function or procedure.
  Enumerated types can't be read or written.
  etc...
- Non-orthogonality is often to simplify implementation.
- LISP is much more orthogonal than Pascal.
Language Evaluation Criteria

→ **Control Statements/Constructs**
  
  Importance and desirability of various control mechanisms varies with the language.

→ **Data Types**
  
  Rich set of data types makes programs much easier to write and understand. Provides abstraction.

→ **Syntax**
  
  Matters more than you think!

  Identifier length, reserved words, layout, etc.

→ **Abstraction**
  
  Must be able to hide details, or complexity is too great.

  process abstraction

  data abstraction
Language Evaluation Criteria

- **Reliability**

  - **Definition:** performs to specifications under all conditions

  - **Impact from:**
    - type checking (or lack thereof)
      - compile-time: *best*
      - runtime: *good*
    - exception handling
      Special language features to help intercept and handle unusual situations. No magic.
      Somewhat controversial.
    - aliasing (Y)
      Two or more names for same memory cell.
      - **PASCAL:**
        var p,q: ^int;
        begin
        new(p);
        q:=p;
      - **FORTRAN:**
        Character *20 Last, First
        Character *40 Name
        Equivalence (Name (1:20), Last),
        (Name (21:40), First)
Language Evaluation Criteria

- **Cost**
  
  - More than just runtime!
    
    time to train programmers
    
    * program development time
    
    compile time
    
    runtime
    
    * maintenance time (>50%)

  - * functions of writability and readability

    => most important
Influences on Language Design

(1) Computer architecture

(2) Programming methodologies

Historically more of (1), moving toward (2). Getting higher and higher-level:

- machine language
- assembly
- FORTRAN
- Algol-like languages
- "very high-level" languages: functional, logic, etc.
The von Neumann Architecture

- John von Neumann at Princeton
  - late 1940's
  - has influenced the design of most programming languages

- Fetch-execute cycle:
  - Control fetches next instr from memory
  - Control decodes instr
  - Execution
    - data from memory to ALU, or
    - data from ALU to memory, or
    - I/O
The von Neumann Architecture

- The von Neumann architecture is reflected in traditional programming languages in two ways:
  - sequential, step-by-step execution of instructions
  - modifiable variables -- "cubbyholes" in memory

- These languages became popular and drove further architectural designs. Vicious circle... other language designs didn't have much chance until recently.
Programming Methods and Methodologies

- **Noted Language Deficiencies**
  - Type Checking
  - Inadequate Control Structures
  - Lack of Exception Handling

- **Novel Approaches to Problem Solving**
  - Data and Process Abstraction
    - Object-Oriented Classes (Simula 67)
      - Encapsulation
      - Data Abstraction
    - Data Flow
  - Concurrency
Translation and Interpretation

- We could build a special machine to execute each language directly, but this is impractical. So how to get a program in a high-level language down to machine code?

- Interpretation

  An interpreter takes statements of a program one at a time and executes them directly as follows:
  - Get next statement
  - Determine actions
  - Perform actions
  - Repeat

  *(look familiar?)*
Notes on Interpretation:

- data is provided to the interpreter as required
- one high-level instruction (HLI) => one sequence of machine-level instructions
- redetermine actions each time HLI is encountered
- highly dynamic

![Flowchart Diagram]

Program (Prog) → Data → Interpreter → Answer
Translation

- **Translation**
  
  → A translator takes a program in language A and produces an equivalent program in language B. If B is "closer" to machine code than A, it’s called a compiler.

- **Notes on translation:**
  
  → high-level program --> machine-level prog
     
    "(not HLI-->MLI)"

  → parsing + code generation

  → decode each statement once
     
    => saves time

  → store expanded version of program
     
    => costs space
Interpretation vs. Translation

- **Interpretation**

  Data
  \[\text{Program} \rightarrow \text{Interpreter} \rightarrow \text{Answer}\]

- **Translation**

  Data
  \[\text{Program} \rightarrow \text{Compiler} \rightarrow \text{Object Code} \rightarrow \text{Computer} \rightarrow \text{Answer}\]

→ Combine translation and interpretation by substituting Interpreter for Computer above.