CONCEPTS OF

PROGRAMMING LANGUAGES

Fall 1995
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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 programers

  *program development time

  compile time

  runtime

  *maintenance time (>50%!)

  → *** functions of writability and readability**

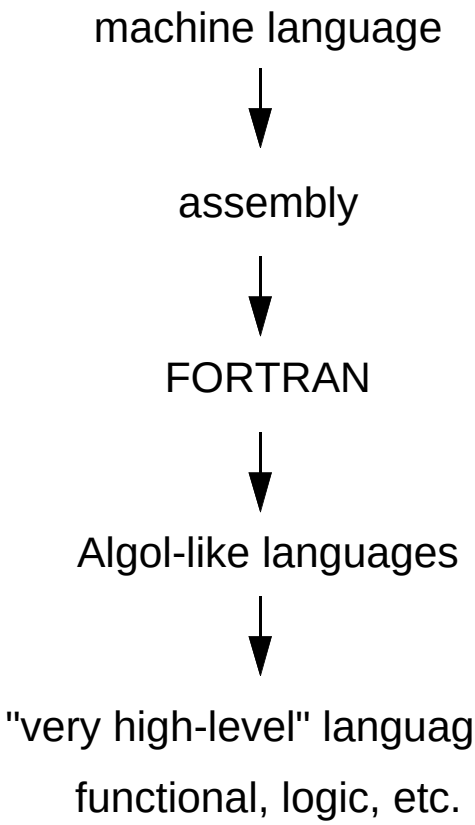
  => most important

Influences on Language Design

(1) Computer architecture

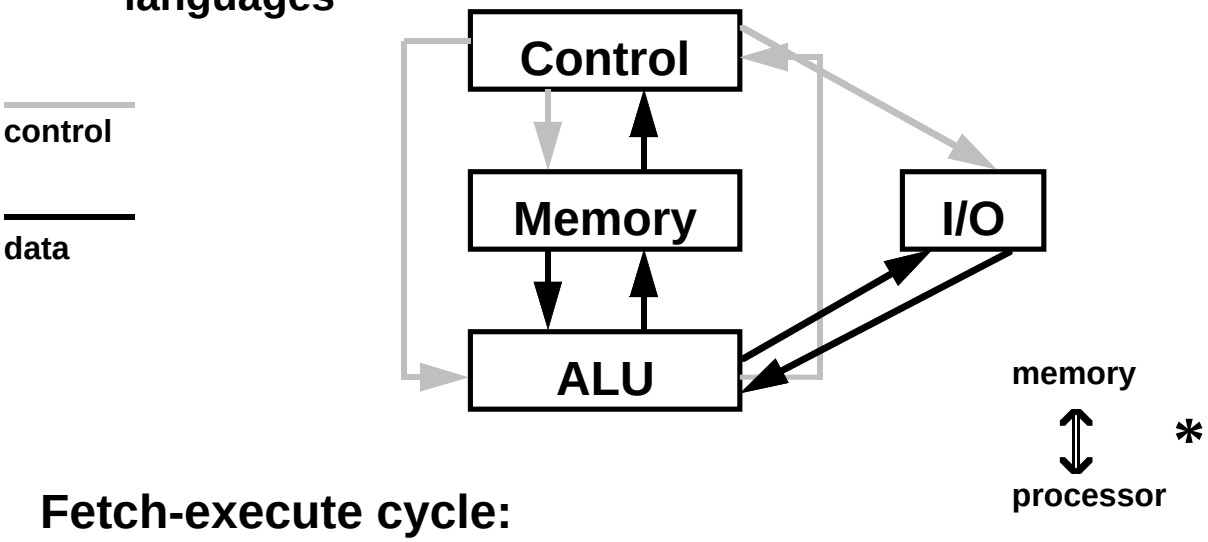
(2) Programming methodologies

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



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 Deficienciences**
  - → **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

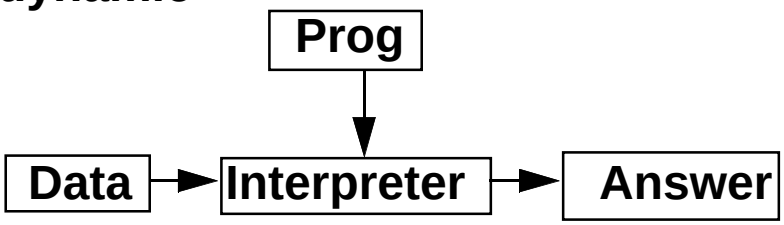
  Perform actions

  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**



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**

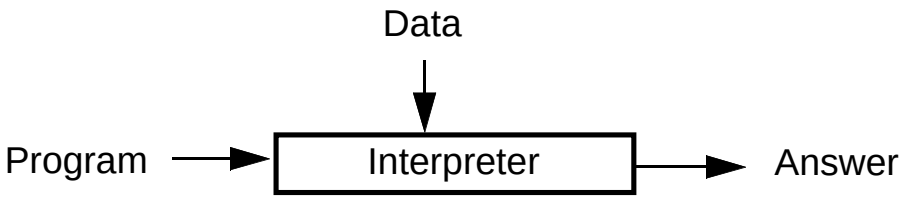
  => saves time

  → **store expanded version of program**

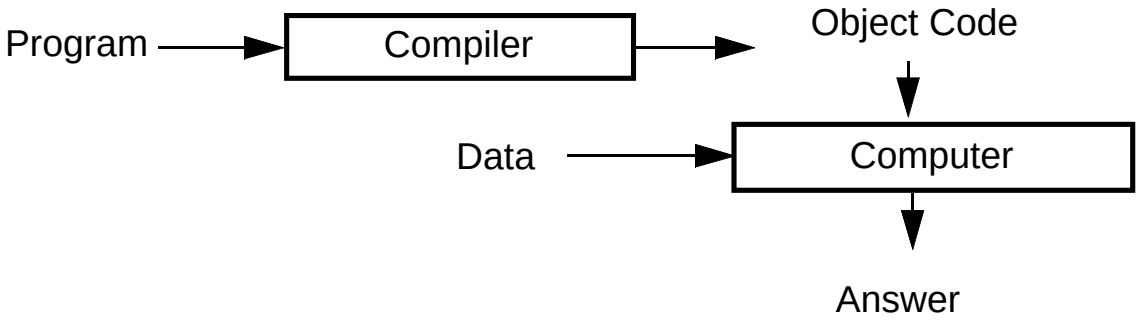
  => costs space

Interpretation vs. Translation

- **Interpretation**



- **Translation**



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