Computer Basics/Algorithms

INFO/CSE 100, Spring 2006

Fluency in Information Technology

http://www.cs.washington.edu/100

Readings and References

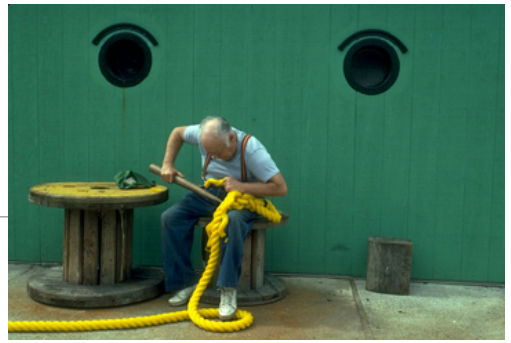
- Reading
  - » *Fluency with Information Technology*
    - Chapters 9, 10

Overview

- During this quarter, we're looking at the actual workings of computer systems
- Organized as "*layers of abstraction*"
  - » application programs
  - » higher level languages: Javascript, SQL, …
  - » operating system concepts
  - » bits, bytes, assembly language
  - » transistors, electrons, photons

Layers of Abstraction

- At any level of abstraction, there are
  - » elements at that level
  - » the building blocks for those elements
- Abstraction
  - » isolates a layer from changes in the layer below
  - » improves developer productivity by reducing detail needed to accomplish a task
  - » helps define a single architecture that can be implemented with more than one organization



Architecture & Organization

- Architecture (the *logical definition*)
  - » defines elements and interfaces between layers
  - » Instruction Set Architecture
    - instructions, registers, addressing
- Organization (the *physical implementation*)
  - » components and connections
  - » how instructions are implemented in hardware
  - » many different organizations can implement a single architecture

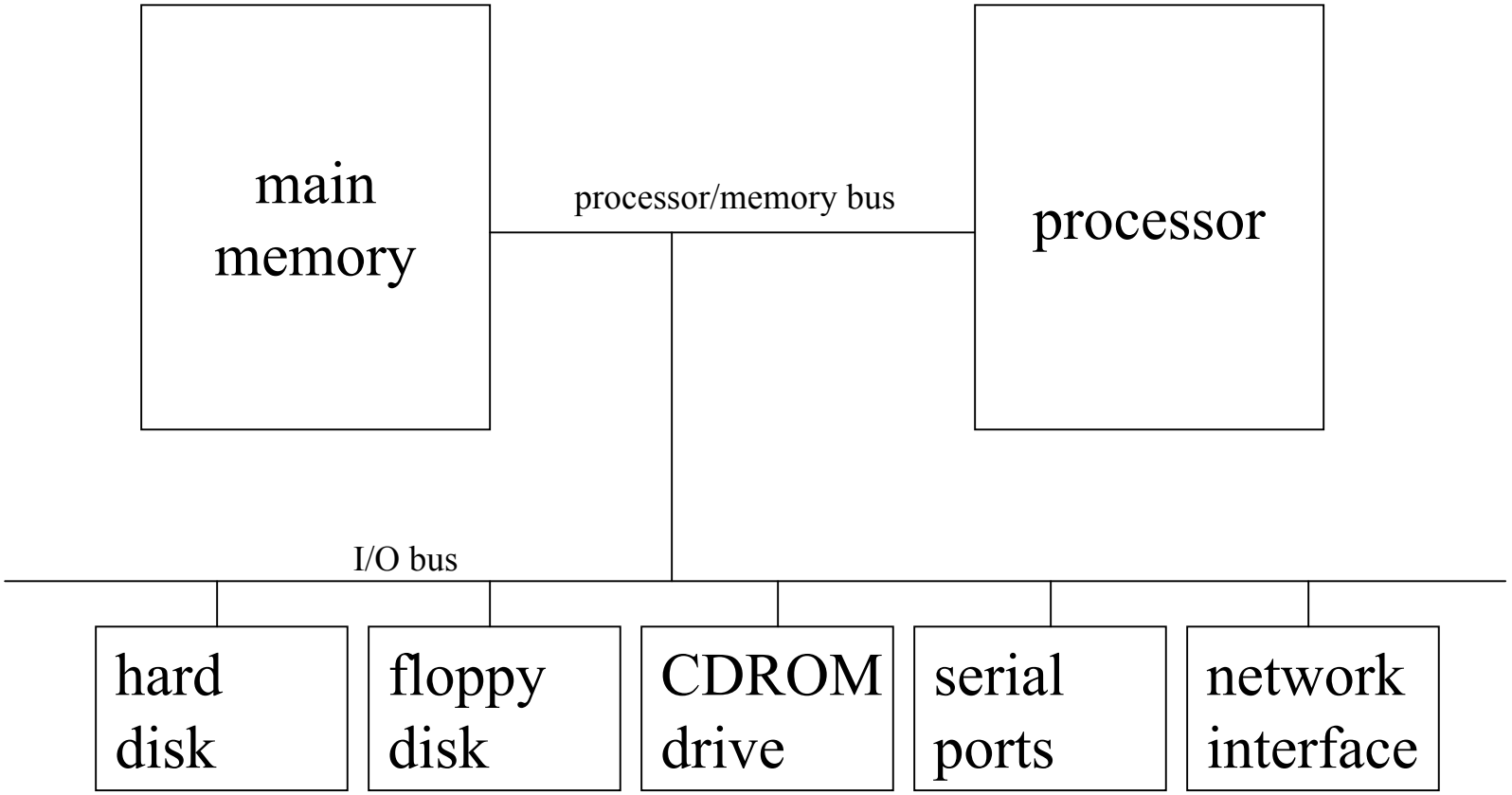
Computer Architecture

- Specification of how to program a specific computer family
  - » what instructions are available?
  - » how are the instructions formatted into bits?
  - » how many registers and what is their function?
  - » how is memory addressed?
- Some examples architectures
  - » IBM 360, 370, …
  - » PowerPC 601, 603, G5, …
  - » Intel x86 286, 386, 486, Pentium, …
  - » MIPS R2000, R3000, R4000, R5000, ...

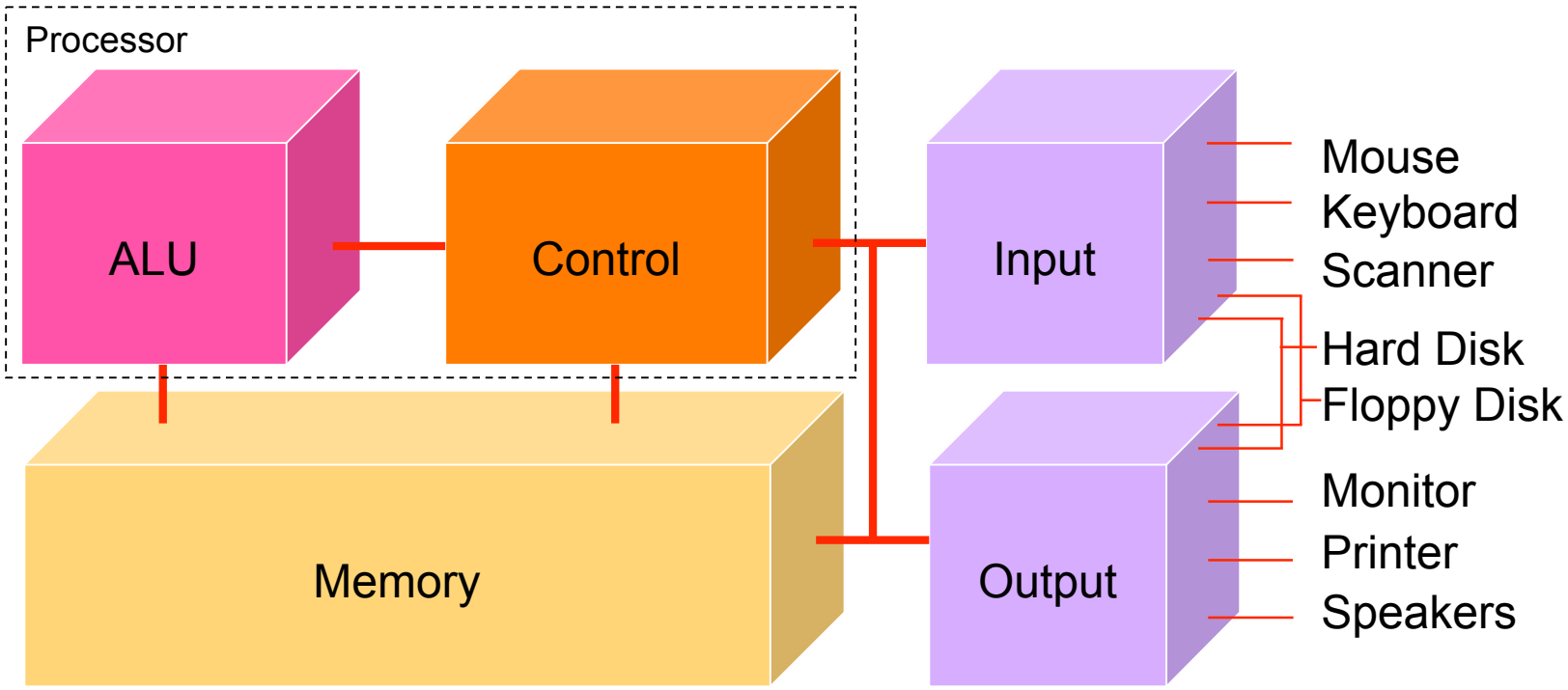
Computer Organization

- Processor
  - » Data path (ALU) manipulate the bits
  - » The control controls the manipulation
- Memory
  - » cache memory - smaller, higher speed
  - » main memory - larger, slower speed
- Input / Output
  - » interface to the rest of the world

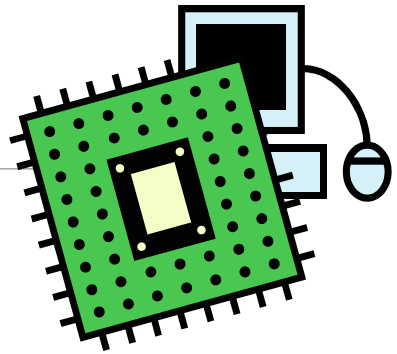
A Typical Organization



Anatomy of a Computer



Computers…



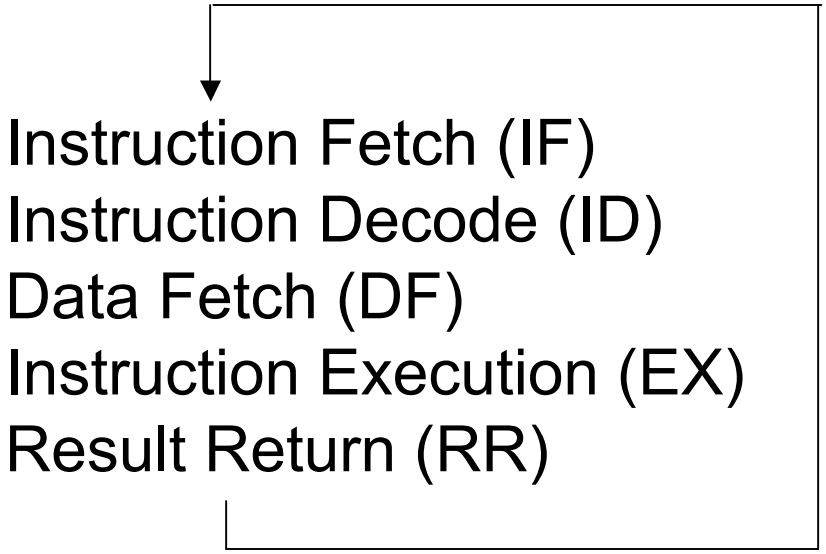
- Deterministically execute instructions
  - » "Deterministically" means that when a computer chooses the next instruction to perform it will make the choice the same way each time
  - » Given the program instructions and the current input, you can always predict *exactly* which instruction will be executed next and what it will do

Computers have no free will and they are not random!

Fetch/Execute Cycle

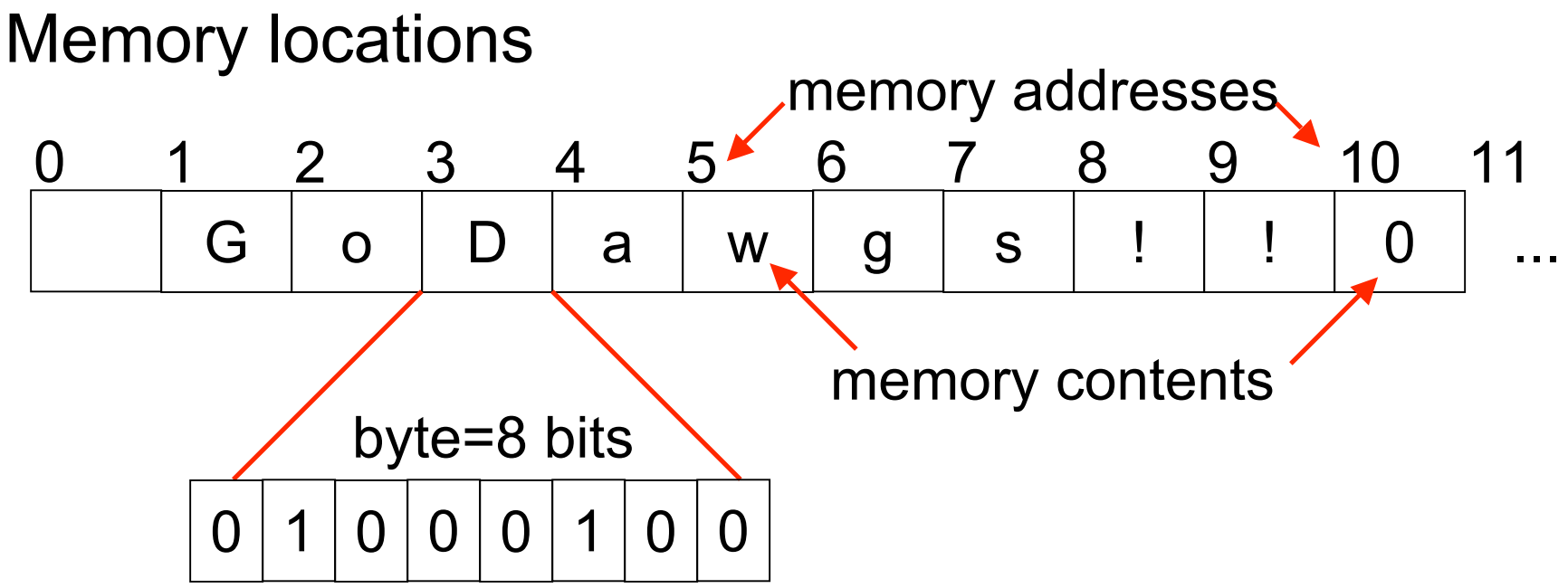
Computer = instruction execution engine

» The fetch/execute cycle is the process that executes instructions



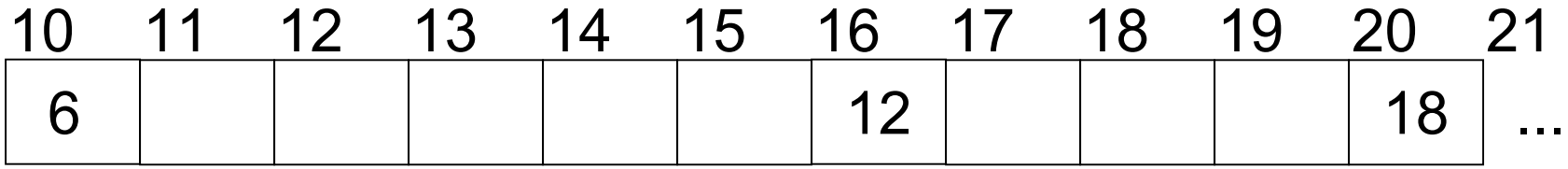
Memory ...

Programs and the data they operate on must be in the memory while they are running



Control

- The Fetch/Execute cycle is hardwired into the computer's control, i.e. it is the actual "engine"
- Depending on the Instruction Set Architecture, the instructions say things like
  - » Put in memory location 20 the contents of memory location 10 + contents of memory location 16
  - » The instructions executed have the form ADDB 10, 16, 20
    - Add the bytes from memory address 10 and memory address 16 and store the result in memory address 20



ALU

The Arithmetic/Logic Unit does the actual computation

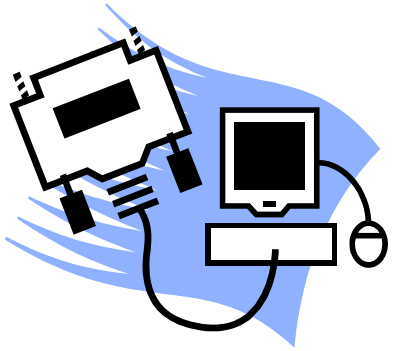
Depending on the Instruction Set Architecture, each type of data has its own separate instructions

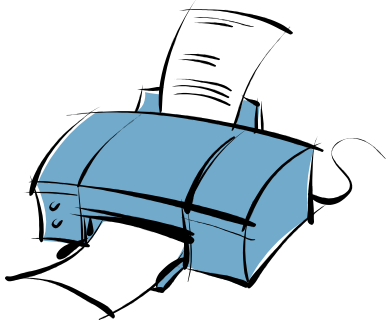
ADDB	: add bytes	ADDBU	: add bytes unsigned
ADDH	: add half words	ADDHU	: add halves unsigned
ADD	: add words	ADDU	: add words unsigned
ADDS	: add short decimal numbers		
ADDD	: add long decimal numbers		

Most computers have only about a 100-150 instructions hard wired

Input/Output

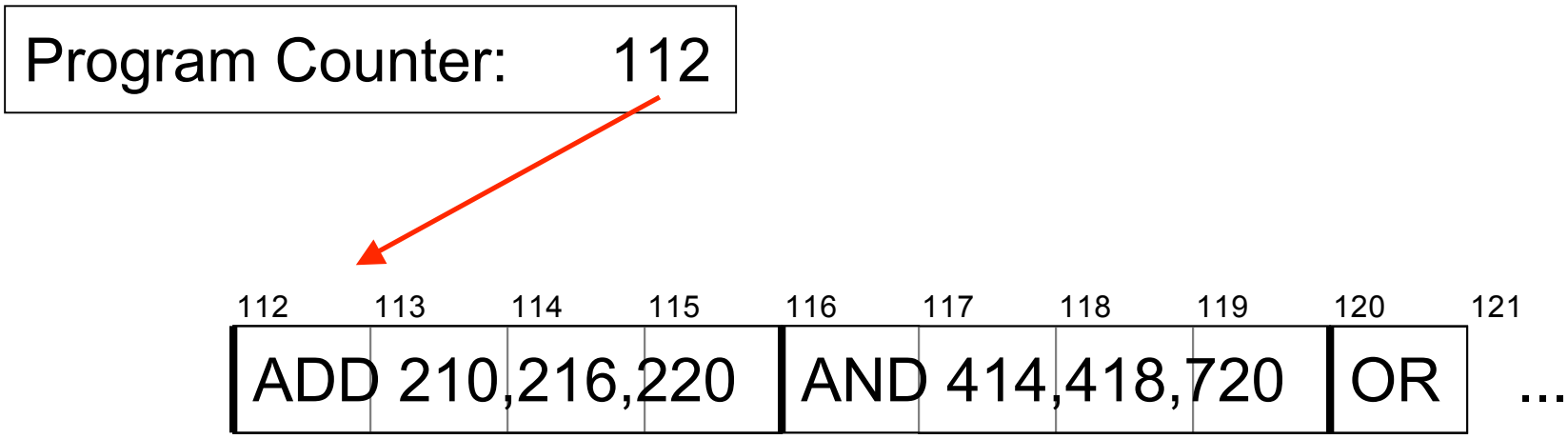
- Input units bring data to memory from outside world; output units send data to outside world from memory
  - » Most peripheral devices are “dumb”, meaning that the processor assists in their operation





The PC's PC

- The program counter (PC) tells where the next instruction comes from
  - » In some architectures, instructions are always 4 bytes long, so add 4 to the PC to find the next instruction



Clocks Run The Engine

- The rate that a computer "spins around" the Fetch/Execute cycle is controlled by its clock
  - » Current clocks run 2-3 GHz
  - » The computer tries do at least one instruction per cycle, depending on the instruction and the availability of memory contents
  - » Modern processors often try to do more than one instruction per cycle

Clock rate is not a good indicator of speed anymore, because several things are happening every clock cycle

Programming

- Converting the complicated tasks we want the computer to do into simple instructions
  - » Computers can be programmed to convert the complex into the simple
  - » Computers only understand binary digits
- Developers created assembly language as a convenient form for instructions
  - » For example; ADDD 2000, 8000, 4000
  - » Translation from assembly to binary is called assembling
- High-level languages are used to complete more complex tasks easily
  - » Translation from a programming language to assembly is called compilation

Algorithm

- Algorithm
  - » a precise, systematic method to produce a desired result

- For example, the placeholder technique for deleting a short string except where it occurs in longer strings is an algorithm with an easy specification:

longStringWithShortStringInIt ← placeholder
ShortString ← e
placeholder ← longStringWithShortStringInIt

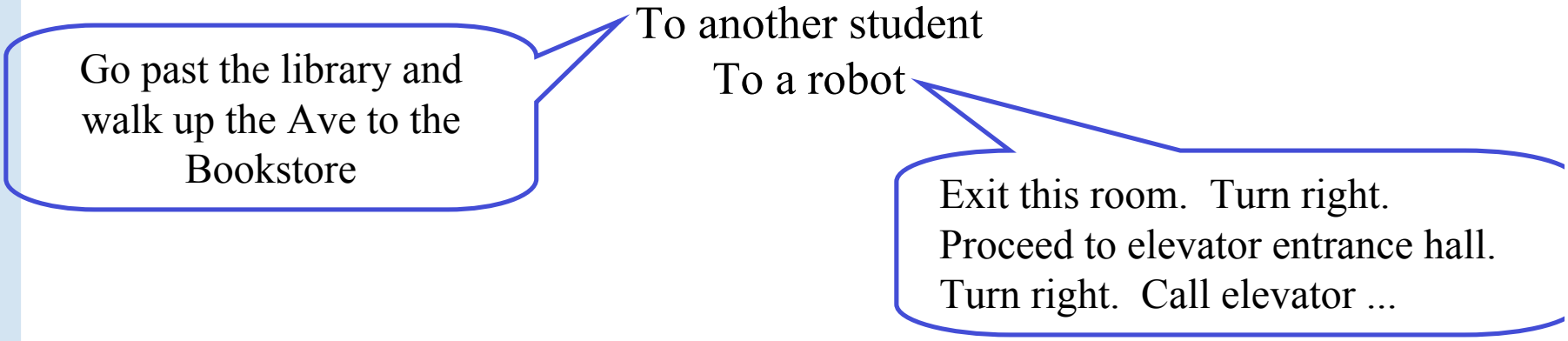
Properties of an Algorithm

- For an algorithm to be well specified it must have …
  - » Inputs specified
    - The range of possible inputs is well defined
  - » Outputs specified
    - The desired output is well defined
  - » Definiteness
    - The steps to take are definite and understandable
  - » Effectiveness
    - The steps must be possible to accomplish
  - » Finiteness
    - A processor that follows the algorithm will eventually finish

Communicating…

- People can fill in missing steps, but can get swamped by lots of details and clutter
- Computers cannot fill in missing steps, but can manage lots and lots of detail without error
- What helps when communicating with computers?
  - » Be *organized* and consistent in all the details
  - » Invent *abstractions* to help specify the basic ideas accurately and consistently
  - » *Analyze* your algorithm and its implementation, because you won't get to interact later

Example: Directions to the Bookstore



- The student operates at a higher level of *abstraction* with a richer *vocabulary* of *shorthands*
- An *algorithm* is a plan for how to accomplish a task
  - » A *program* is an implementation of an algorithm
- Good algorithms (at any level of abstraction) require precision

Algorithm Analysis: What is it?

- What is an algorithm?
  - » A sequence of steps that accomplishes a task
- Many different algorithms may correctly solve a given task
  - » can it be implemented with available equipment?
  - » will it complete within this lifetime?
  - » will it require gigabytes of memory?

Algorithm Analysis: Why do it?

- Understand the mathematical fundamentals needed to analyze algorithms
- Learn how to compare the efficiency of different algorithms in terms of running time and memory usage
- Study a number of standard algorithms for data manipulation and learn to use them for solving new problems

Programs vs Algorithms

- A program is an algorithm specialized to a particular situation
  - » an Algorithm

    longStringWithShortStringInIt ← placeholder

    ShortString ← e

    placeholder ← longStringWithShortStringInIt
  - » a Program that implements the Algorithm

    ↲↲ ← # // replace double <newlines> with <#>

    ↲ ← e // delete all single < newlines>

    # ← ↲↲ // restore all double <newlines>

Programming as Communication

- When we write a program, we are communicating with
  - » the computer
  - » other people
- The computer reads our program as the set of instructions that it should perform
  - » It just needs to know how, not why
- Other people read our programs to understand how and why
  - » Programs that don't work (bugs)
  - » Program evolution - new features
  - » Performance improvement

An algorithm to alphabetize CDs

define variable named *Artist*
    use *Artist* to refer to the name of the group that made a CD
for all slots in the rack starting at one end
    call the current slot *alpha*
    for all the remaining slots in the rack
        call the next slot *beta*
        Exchange?
            If *Artist* of the CD in the *beta* slot is earlier in the alphabet than the *Artist* of the CD in the *alpha* slot, interchange the CDs
    next *beta*
 next *alpha*
done

Another sorting demo…

- With plastic bottles!

Summary

- We can figure out many algorithms on our own, abstracting from specific cases
- We can learn from others who have studied particular algorithms in depth
- We abstract parts of an algorithm or program to understand them
  - » Thinking of how the program works and reasoning about its properties allows us to know why an algorithm works … and then we can get the computer to do it for us