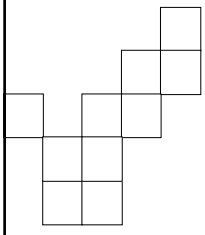


Algorithmic Thinking

What steps does a computer go through to solve a problem? To be effective computer users, we need to learn the steps involved.

Thinking algorithmically is the first one.

Unambiguous Instructions

- An *algorithm* is a systematic method for deterministically producing a specified result. In other words, step-by-step instructions that, if followed, get you the same result every time.
- There are two main parts to an algorithm – giving the instructions and following the instructions
  - Giving the instructions (specifying the algorithm) – in this class, from now on, that will be the programmer
  - Following the instructions (executing the algorithm) without the help or intervention of the programmer – once again, from this point on we will consider the computer to be doing this
- Assume that the agent giving the instructions will not be the agent who follows them

You're Already Familiar With Algorithms

- Recipes
  - Recipes are examples of algorithms written by chefs (programmers) and followed by cooks (computers) to produce a specified food (deterministic result)

> S'mores: Place a toasted marshmallow on a Graham cracker and then place a square of chocolate on top

- Driving Directions
  - Written by agents (people) and followed by drivers to get to a specific destination

The 5 Properties of Algorithms

- All algorithms must have certain properties if a computer is to execute them successfully without intervention by the programmer
  - Input Specification
  - Output Specification
  - Definiteness
  - Effectiveness
  - Finiteness

Input Specification

- The *input* is the data that will be transformed by the algorithm to create the output
- The input must exist in a format the computer can access and manipulate
- When giving an algorithm, one needs to state:
  - The types of data expected: whole numbers, letter strings
  - The number of data items expected (the amount so that the computer will know when it has reached the end of the data)
  - The structure, if any, of the data expected – a list, a table, etc.

Output Specification

- The *output* is the result of the computation – the description of the result often forms the name of the algorithm
- The output must be specified in a format that the computer can express (such as on screen, or with audio)
- The features specified are the same as for the input:
  - The types of data forming the result
  - The number of data items forming the result
  - The structure of the result

Definiteness

- An algorithm must be explicit about how to work the computation
- Definiteness comes by giving commands that state unambiguously what to do, in sequence
- The commands may be …
  - Conditional, which requires that a decision to be made. This requires explicit directions on how to respond to all different outcomes
  - Repeated (Loops), which requires explicitness about when to stop the repetition

The definiteness property assures that the agent executing the instructions will ALWAYS know what command to perform next

Effectiveness

- Effectiveness assures that the agent following the instructions (the computer) is able to do so without intervention
  - No additional inputs, special talent, creativity, clairvoyance or help from Superman or other beings
- Effectiveness is achieved by reducing the task to the primitive operations known to the computer
- Definiteness assures that the computer ALWAYS know what command to perform next
- Effectiveness assures the computer CAN accomplish the command

Finiteness

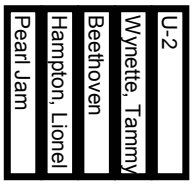
- An algorithm must eventually end / terminate with either
  - The "right" output
  - An indication that no solution is possible
- An algorithm that never terminates is useless since it is impossible to know the difference between continued progress and "stuck"
- Finiteness is relevant to computer algorithms since they typically repeat instructions

```
  3.3
3 )10.000000000 …
  9
  10
  9
  1
```


How Precise (Definite, Effective and Finite) Can You Be?

- Write an algorithm to sort 5 numbers from largest to smallest
- Take out a scratch piece of paper. Tear it into 5 small pieces. Write the following numbers, one on each piece of paper: 5, 19, 38, 7, 9
- Shuffle them around
- Take out another piece of paper. Write your name on it.
- Write down the steps (an algorithm) to sort these 5 numbers. Note: You can only view and compare 2 numbers at any single point in time

Alphabetized CDs



- Input: Unordered CDs filling a slotted rack
- Output: CDs in slotted rack, alphabetized

Algorithm for Alphabetizing

1. *"Artist_Of"* means the name of the group
2. Pick one end of the rack to be the beginning of the alphabetic sequence. Call that end's slot the *"Alpha"* slot
3. Call the slot adjacent to the *Alpha* slot the *"Beta"* slot
4. If the *Artist_Of* the CD in the *Alpha* slot is later in the alphabet that the *Artist_Of* the CD in the *Beta* slot, then interchange the CDs
5. If there is a slot following the *Beta* slot, begin calling it the "*Beta"* slot and go to step 4; otherwise, continue on
6. If there are two or more slots following the *Alpha* slot, then begin calling the slot following the *Alpha* slot, *"Alpha"* and the slot following it the "*Beta"* slot and go to step 4; otherwise, stop

Different Ideas for Sorting Algorithms

- Insertion Sort
  - Make the first number a list by itself – it is already sorted
  - "Insert" each number, one at a time, into the correct place in the list; shift the other numbers if you need to
- Bubble Sort
  - Compare each pair of numbers, one pair at a time; if the pairs are out of order, swap them.
  - Keep doing this step until you go through the complete list without having to swap a single pair
- Exchange Sort
  - Go through the list, at each step swapping the smallest number into the first slot in the list
  - Repeat this step with each successive position in the list

Is It An Algorithm, A Program, Or Both?

- A program is simply an algorithm specialized to a particular situation
  - Alphabetize CDs, if it were a program, would be called an instance of the Exchange Sort algorithm
- Exchange Sort can be specialized to other cases
  - Sort CD's by other criteria – title, genre, etc.
  - Sort books by title, author or ISBN number
  - Sort homework papers turned in by student ID, or Name
- The algorithm, being a process with only a limited number of specifics, is more abstract than a program
- Therefore, all programs are algorithms, but not all algorithms are programs