The Role of Algorithm in Computing

Professor: Dr. Kahrobaei

City Tech (CUNY)

Questions about Algorithms!

- What are algorithms?
- Why is the study of algorithms worthwhile?
- What is the role of algorithms relative to other technologies used in computers?

Definition of Algorithms

- Informally, an ***algorithm***, is any well-defined computational procedure that takes some value, or set of values, as ***input***, and produces some value, or set of values, as ***output.***

- We can also view algorithm as a tool for solving a well-specified ***computational problem.*** The statement of the problem specifies in general terms the desired input/output relationship. The algorithm describes a specific computational procedure for achieving that input/output relationship.

Examples of algorithms

- Sorting a sequence of numbers into nondecreasing order.
- Here is how we formally define the ***sorting problem***:
- **Input:** A sequence of n numbers $\langle a_1, a_2, \ldots, a_n \rangle$
- **Output**: A permutation (reordering) $\langle a'_1, a'_2 \ldots, a`_n \rangle$ of the input sequence such that

$$a'_1 \leq a'_2 \leq \ldots \leq a`_n$$

Instance of a problem

- Such an input sequence is called an ***instance*** of the sorting problem.
- In general, an instance of a problem consists of the input (satisfying whatever constraints are imposed in the problem statement) needed to compute a solution to the problem.

Correct Algorithm

- An algorithm is said to be ***correct*** if, for every input instance, it halts with the correct input.
- We say that a correct algorithm ***solves*** the given computational problem.
- An incorrect algorithm might not halt at all on some input instances, or it might halt with an answer other than the desired one.
- Contrary to what one might expect, incorrect algorithms can sometimes be useful, if their error rate can be controlled.

Types of algorithms

- An algorithm can be specified in English, as a computer program, or even as a hardware design.
- The only requirement is that the specification must provide a precise description of the computational procedure to be followed.

What kind of problems are solved by algorithms?

- The Human Genome project
- Internet
- Electronic commerce
- Manufacturing and commercial settings
- Road map-shortest path
- Finding product of matrices
- Solving equation $ax = b \pmod{n}$ where a and b are integers and looking for efficient methods.
- We are given n points in the plane, and we wish to find the convex hull of these points.

Two characteristics that are common to many interesting algorithms

- 1. There are many candidate solutions, most of which are not what we want. Finding one that we do want can present quite a challenge.

- 2. There are practical applications. Of the problems in the mentioned list, shortest path provides the easiest examples.

Data structures

- A data structure is a way to store and organize data in order to facilitate access and modifications.
- No single data structure works well for all purposes, and so it is important to know the strengths and limitations of several of them.

Techniques

- In this course we will teach you techniques of algorithm design and analysis so that you can develop algorithms on your own, show that they give the correct answer, and understand their efficiency.

Hard problems

- We are interested in efficient algorithms.
- The usual measure of efficient is speed, i.e. how long an algorithm takes to produce its result.
- There are some problems, however, for which no efficient solution is known. Which are known as NP-complete.

Why NP-complete problems are interesting?

- 1. Although no efficient algorithm for an NP-complete problem has ever been found, nobody has ever proven that an efficient algorithm for one cannot exist. In other words, it is unknown whether or not effiecient algorithms exist for NP-complete problems.
- 2. The set of NP-complete problems has the remarkable property that if an efficient algorithm exists for any one of them, then efficient algorithms exist for all of them.

Why NP-complete problems are interesting?

- This relationship among the NP-complete problems makes the lack of efficient solutions all the more tantalizing.
- 3. several NP-complete problems are similar but no identical, to problems which we do know of efficient algorithms. A small change to the problem statement can cause a big change to the efficiency of the best known algorithm.

NP-complete problems

- It is valuable to know about NP-complete problems because some of them arise surprisingly often in the real world applications.