[MANUSCRIPT] A Brief Survey of Elementary Algorithmic Literacy

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The ability to dismantle a problem and think algorithmically has shown to be more and more relevant and effective in modern life. The basic capability to leverage algorithms, or what we refer to as "algorithmic literacy"—beyond the reformation of the educational landscape based on computer usage—is useful to many fields and requires two general components or stages of development: first, the training of basic algorithmic techniques working on abstract mathematical structures, as instructed in a common modern course of high school or collegiate computer science curriculum, and second, a translation for the practice of problem solving skills in social settings. At its core, observation is fundamental as it shapes the content of data or information we absorb in as well as the quality of the information; good observations lead to good judgments and, subsequently, wise decision making and successful operations of task. In this brief survey, we aim to provide a rudimentary tutorial on the elements of algorithmic literacy and accompany it with selected examples in social life, given the author's respective, cumulative disciplinary perspectives. We hope to shed lights on the pedagogical concern of what to teach students at secondary and early collegiate level as modern problem solving and decision-making skills, and how such methodological skillset can be taught in classrooms.

Introduction

Algorithms are what drives our software and hardware machineries in our modern information systems. Nearly half a century into the Internet era, people who designed and "evolve" algorithms are no longer alone "held accountable to society," in which regard greater need arises for education in algorithmic literacy, as well as training in ethics and relevant issues (Rainie & Anderson, 2017). "Information literacy" is a broader concept that encompasses the ability to "recognize when information is needed and have the ability to locate, evaluate, and effectively use the needed information," according to a 1989 report by the American Library Association's Presidential Committee (1989).

With or without the usage of computing and mechanical facilities, the highly overlapped algorithmic literacy is meant to be autonomous from information literacy in that it leans toward problem-solving skills and philosophical paradigms; Bell at al. (2009) of University of Canterbury, New Zealand had devised a curriculum to teach computing skills without a computer in their "Unplugged" project, using primitive tools and vivid, real life human interactions. The 2011 review "Algorithm Unplugged" also attempts to distill the impact of algorithms based on a lens into science, medicine, production, logistics and beyond (Berthold et al., 2011).

In the educational circle nowadays, there is a prevalent belief to some degree that every student in our modern society should know something about algorithms, and the philosophy in computer science is good for everyone. An ancient concept, algorithms in our modern terms are central to traditional scientific, technological disciplines, but gradually grew also more prevalent into the humanities side of disciplines. For the discipline of computer science, it is central to all kinds of computing tasks, which alternately inspires other tasks and fields, such as operational research and logistics, decision making in businesses, et cetera. Algorithmic literacy can serve as one of the bridges to the science of decision for the pursuit of "skillful judgment formation and decision-making" (Alliance for Decision Education, 2022), which demands the learner to think and address problems procedurally and systematically.

Essentials of Algorithmic Literacy

Several pillars make up the rough image of algorithmic literacy, minimally and not inclusively. It starts with a sensible and acute ability of observation which opens a lens to further discoveries, analyses, and devising of tasks.

Observation

We see, sense every day and everywhere, but we might not observe well all the time. Wester's 1913 dictionary defines "observe" as to take notice by some appropriate conduct; it is to conform one's action or practice, and to "heed"—mind and regard with care. For example, when your doorbell rings, test if you could, afterwards, remember or have counted the number of footsteps it took from your living room to front door to answer the bell. To characterize, describe by gestures or in words something that we already observed, is another important, extended skill of observation: how do we precisely describe a location, a shape, or any other feature? To achieve this, we are demanded to stretch our minds to think hard on these aspects of what we observe, and therefore being enhanced in our observational skills.

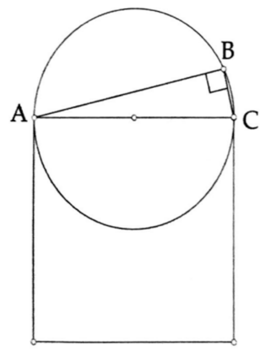

Figure 1. Configuration of angle on circumference

For a simple circumference angle theorem diagram, on one hand we want to use appropriate, precise descriptive language to characterize the plane geometry objects and their relative positions; on the other, when given this configuration, we may also want to infer by looking at certain parts of the diagram what the intent of demonstration is. When given a sequence of numbers, say

$$\{70, 31, 9, 78, 36, 73, 50, 40, 21, 75\}$$

then how can we tell the smallest among it all, and can we explain *why* we landed on that conclusion? Such reflective questions help us evaluate the effectiveness of our observation.

The Concept of Data

When we perceive the world as humans, we will acquire information that is carried in the form of what we refer generically as “data”, the linguistic meaning of which is the plural form of the Latin word “datum” for “things given”; its earliest use in English was from the 1600s, and in 1946 it was used to describe “transmissible and storable computer information” and “data processing” in 1954. Information is measured and often stored in the basic unit of a “bit”, the smallest possible digit that is *binary*, either yes (one) or no (zero).

It seems then that data is pervasive and can be anything: several photographs of a cat could be considered a “dataset”. In most practical situations, though, we focus on and leverage *numeric* data, data that consist of certain types of numbers primarily integers and real numbers. An important feature of such data that is worth noting is that they are *numerable*, or that they can be compared and traversed or "numerated".

Fundamental Data Structures

Data structures are the actual containers of data elements, similar to the role of symbolic placeholders in algebra and in arithmetic. A typical, abstract type of data structures is called a *set* or a *dictionary*, one that supports the following operations,

1. Insert: to add a new element into some/any place within the data structure;
2. Remove: to take away a specific element from data structure while not destroying the data structure;
3. Find: to search and locate a specific element (usually by its numeric value or features) inside a data structure; such element may not exist in the structure in the first place.

which is commonly used. In practice, to realize the above set data structure, there are two instantiations of data structures called the *arrays* and the *linked lists*. An array allows retrieval or modification of any element at a fast speed, while an element can be added into a linked list very easily.

Algorithms

The word algorithm is derived from the nineth-century Persian mathematician Muḥammad ibn Mūsā al-Khwārizmī; it describes a precise rule (or set of rules) specifying how to solve some problem; according to Webster's 1913 dictionary, an algorithm is a set of procedures guaranteed to find the solution to a problem. It is also a "conceptual recipe" to do some task. What makes an algorithm "good"? First, it shall always *terminate* and produce correct results. Second, it is expected to be *efficient*: the leverage of computational resources minimizes running time, memory, network bandwidth, and so on. Lastly, we hope an algorithm is simple to describe, paraphrase, and analyze with.

Pseudocode

The pseudocode of an algorithm is a "plain language" description of the steps in it or another hardware/software system that implements it. For example, an algorithm of sorting applies on a sequence of numbers by changing the orders of elements until they are sorted, either ascending or descending, such that any consecutive pairs of elements are all in the ascending (or all descending) order. A "bubble sort" algorithm can be described by the following pseudocode:

Repeat for *n* times (*n* is the total number of elements):

Iterate through all elements, and at the *i*-th location:

If element *i* and element (*i*+1) were out of order:

then swap them

which tells exactly how to execute a procedure that fulfills a certain task, here to have the numbers sorted. Each logical branch such as the "if … then …" statement defines a decision to let the algorithm execute according to the corresponding rules assigned.

Example 1: The "Eisenhower Matrix" Time Management Tool

American educator introduced a neat tool called the *Eisenhower matrix* to help determine the priorities and the urgency of tasks (Covey, 1989), which is also known as the four-quadrant to-do list. We can always change the plan, but only if we already have one, and once we have a plan we want to reshuffle them by their level of importance and urgency, and that is where the Eisenhower matrix comes in. The process of making decision here, also viewed as an algorithm, is to collect tasks as data, and then "sort" them two-dimensionally according to importance and urgency, as shown in Figure 2. If we could complete tasks on time, such that more items are clustered toward the top-right corner with less urgency and more importance, then it might be a good sign of wise decision making and execution of plans.

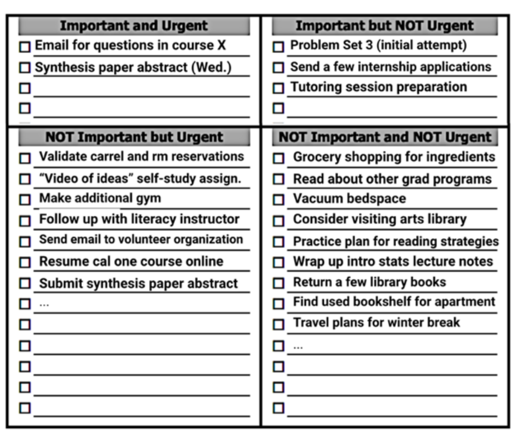

Figure 2. Example of an Eisenhower matrix.

Example 2: Career Decision Making

Through the process of academic and professional life, we are regularly doing career planning and decision making. As a lifelong process, career decision making takes time and training. The Office of Career Strategy has suggested a five-step procedure to decision making in career planning (Yale Office of Career Strategy, 2022) which consists of skills, academic considerations, priority choices, and evaluation:

1. To assess oneself regarding skills, interests, personality, and values to determine what types of jobs are best suited;
2. To identify and research options of career choices as well as networking;
3. To evaluate choices made and prioritize;
4. To take actions on certain options;
5. To reflect and re-evaluate.

Through iterative implementing these steps, an inquirer would gain maturity in the decisions made and direct themselves into better judgment.

Conclusion

Being capable of reasoning and problem-solving with quantitative data assumes an integration of skills. Contemporary educational psychologist Glenda Price suggests that teaching logical thinking, analysis of evidence, and “statistical reasoning” will be of primary importance for twenty-first century context, compared to traditional algebraic skills. Algorithmic literacy involves the language of mathematics, and our curriculum design needs to reflect this in order to compensate what students are not yet fluent with. Once the ingredients are ready to perform more difficult tasks, the learner can pave through their ways more smoothly to make harder decisions, as well as designing algorithmic solutions to the issues addressed.

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