Algorithmic Thinking with Python

SEMESTER S1(Common to All Branches)

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Outline

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PROBLEM-SOLVING STRATEGIES:- Problem-solving strategies defined, Importance of understanding multiple problem-solving strategies, Trial and Error, Heuristics, Means-Ends Analysis, and Backtracking (Working backward).

Outline

Examples of Problem

In our daily life, we encounter problems that are big and small.

Some are easy to solve and some tough to solve.

Some required structured solution and some unstructured approach.

Some are interesting and some are not.

Example 1:

Suppose you discover that you lost your wallet that is of great sentimental value when back from college. How do you regain the wallet?

Where did you actually drop the wallet?

It might have dropped at the college or on the way back home? If at the college,was it in the classroom or playground or the library or somewhere else?

These questions must be answered before we understand to regain the wallet. Assumptions should not be made without basis. Irrelevant information (sentimental value) should be ignored. Suppose wallet was lost in the library. How do you recover the wallet?

Example 2:

In a circle, a square with side length 2a is inscribed. What is the area of the circle?

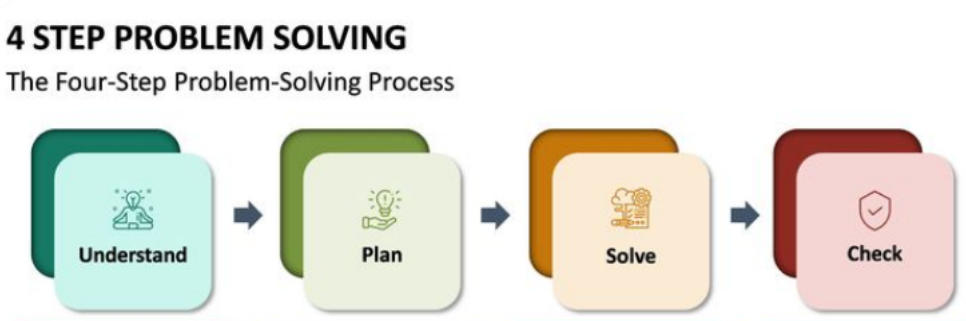
This is a well-stated problem in geometry. We must understand the problem and devise a plan for solving it. Determine the input (the length of each side of the square) and the output (the area of the circle). You use suitable notation to represent the data, and you examine the relationship between the data and the unknown, which will often lead you to a solution. This involves the calculation of some intermediate result, like diagonal of the square. We make use of the domain knowledge of basic geometry.

PROBLEM SOLVING

Definition: Problem solving is the process of transforming the description of a problem into the solution by using our knowledge and by relying on our ability to select and use appropriate problem-solving strategies and tools to implement.

STEPS:

- Problem solving is the act of **defining a problem;**
- Determining the **cause of the problem;**
- Identifying, prioritizing, and selecting **alternatives for a solution;**
- And then **implementing a solution.**



Problem Solving Chart

Phase 1: Understanding the problem.

- Differentiate fact from opinion, Specify underlying causes.
- Consult each faction involved for information.
- State the problem specifically.
- Draw a figure. Introduce suitable notation if required.
- Identify what standard or expectation is violated Determine in which process the problem lies and avoid trying to solve the problem without data.

Phase 2: Devising a plan.

- Have you seen the same problem or in a slightly different form?.
- Do you know a related problem with given known.
- Look at the unknown! Try to think of a familiar problem having the same or similar unknown.
- Split the problem into smaller, simpler sub-problems.
- If you cannot solve the proposed problem , solve some related problem or solve a more general problem. Or a special case of the problem. Or solve a part of the problem.

Phase 3: Carrying out the plan.

- Carrying out your plan of the solution, check each step.
- Can you see clearly that the step is correct?
- Can you prove that it is correct?

Phase 4: Looking back

- Can you check the result?
- Can you derive the result differently?
- Can you use the result, or the method, for some other problem?

Classes of Problems

Problems can be classified into two categories

1. Well-defined problems
2. Ill-defined problems.

Well-defined problems comes with the following properties:

- The problem has a clearly defined given state.
- There is a finite set of operators
- The problem has a clear goal state:

Well defined problem Example

The game of chess

Initial state is defined by the players lined up on the chess-board for the opening move. The final goal state is defined as checkmate. The operators are the legal moves of the game that help achieve the sub-goals and eventually the final goal of checkmate.

The Hanoi Tower Problem

The player is given a set of rules to start with-the discs of different sizes are stacked on the first of three pegs. The problem is well defined- the discs have to be moved to the third peg, while doing so, only the top disc can be moved to the other peg, with the restrictions that only one disc can be moved at one time and no larger disc can be placed on a smaller disc.

Ill defined problems

- no clear initial conditions.
- no completely specified goals.
- a large number of unpredictable solutions.
- no defined set of operators or algorithms.

Example: “Please paint a beautiful picture”
Since solutions to ill-defined problems may be ambiguous, it is not possible to forecast whether an algorithm may fit the initial requirements. For this reason, ill-defined problems cannot be solved in a routine way.

Outline

Problem-solving strategies

An individual uses various kinds of methods or strategies to solve problems.
Some strategies may take a longer time but definitely gives an answer. On the other hand some strategies take less time but do not always guarantee success.
These strategies can be mainly classified as

- Trial and Error
- Algorithm and Heuristic
- Means-Ends Analysis
- Backtracking

Importance of Understanding Multiple Problem-Solving Strategies

Different problems often require different approaches, and being familiar with multiple strategies allows for greater flexibility and adaptability. For example, some problems might be best solved through a systematic trial and error method, while others might benefit from a more analytical approach like means-ends analysis. By knowing several strategies, one can quickly switch tactics when one method does not work, increasing the chances of finding a successful solution.

Benefits of Multiple Problem-Solving Strategies

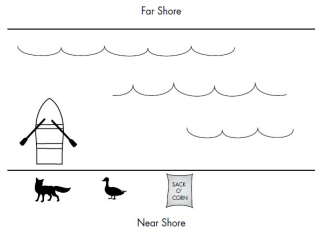
- **Adaptability:** Different problems require different approaches which allows for flexibility and adaptability in problemsolving.
- **Efficiency:** Some strategies are more effective for specific types of problems. They can save time and resources.
- **Improved Outcomes:** Diverse strategies offer multiple perspectives and potential solutions, increasing the likelihood of finding optimal solutions.
- **Skill Development:** Exposure to various strategies enhances cognitive skills, critical thinking, and creativity.

Trial and Error

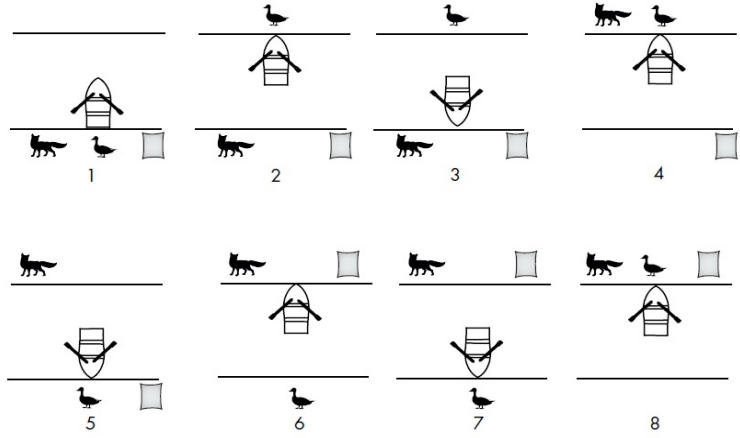
One of the most common problem-solving strategies is trial and error. This method, often utilized in simple situations, involves experimenting with different approaches until a satisfactory outcome is achieved.
For example, say the problem is that your Wi-Fi isn't working. You might try different things until it starts working again, like restarting your modem or your devices until you find or resolve the problem. When one solution isn't successful, you try another until you find what works.

PROBLEM: HOW TO CROSS THE RIVER?

A farmer with a fox,a goose, and a sack of corn needs to cross a river. The farmer has a boat, but there is room for only the farmer and one of his three items. Unfortunately, both the fox and the goose are hungry. The fox cannot be left alone with the goose, or the fox will eat the goose. Likewise, the goose cannot be left alone with the sack of corn, or the goose will eat the corn. How does the farmer get everything across the river?



Solution: HOW TO CROSS THE RIVER?



Trial and Error

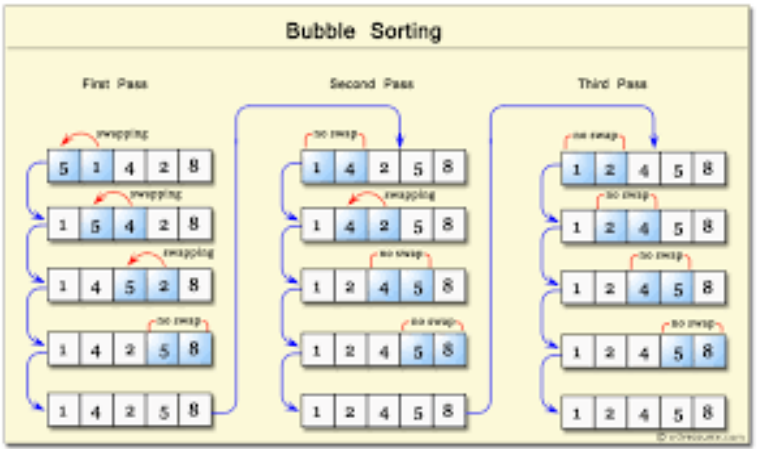
The trial-and-error problem-solving strategy involves attempting different solutions and learning from mistakes until a successful outcome is achieved. It is a fundamental method that relies on experimentation and iteration, rather than systematic or analytical approaches. Consider the situation where you have forgotten the password to your online account, and there is no password recovery option available. You decide to use trial and error to regain access:

Steps to recover password

1. Initial Attempts: You start by trying passwords you commonly use. Eg: ”password123,” ”Qwerty2024,” etc
2. Learning from Mistakes: None of these initial attempts work. You try variations incorporating your birthdate, pet’s name, or favorite sports team.
3. Refinement: After several failed attempts, you remember you recently started using a new format for your passwords, combining a favorite quote with special characters. You attempted various combinations, such as”ToBeOrNotToBe!” and other combinations.
4. Success: Eventually, through persistent trial and error, you hit upon the correct password: ”ToBeOrNotToBe!2024.”

Algorithm

Algorithms are generally procedures that, if applied correctly, give accurate solutions.**An algorithm is a set of precise and unambiguous instructions that can be followed to achieve a specific goal or solve a particular problem.** For example, if you want to sort a list of numbers in ascending order, you can use an algorithm that compares each pair of numbers and swaps them if they are out of order. An algorithm can be implemented in any programming language, and it should always produce the same output for the same input.


Bubble Sorting
First Pass
Second Pass
Third Pass
swapping
no swap

Heuristic

Heuristics are a general problem-solving strategy that may not always guarantee an optimal solution but can be more practical or efficient in certain situations. Heuristics are often used when the complexity of a problem makes it impractical to find an optimal solution, relying instead on educated guesses or rules of thumb to guide decision-making. It is also used when lesser time is required to find a solution.
The benefit of heuristics in helping us reach decisions fairly easily also has a disadvantage: the solution provided by the use of heuristics is not necessarily the best one.

Heuristic Examples

Heuristics are shortcut strategies that people can use to solve a problem at hand.
If you find yourself sitting in a traffic jam, for example, you may quickly consider other routes, taking one to get moving once again. When shopping for a new car, you might think back to a prior experience when negotiating got you a lower price, then employ the same tactics.
While heuristics may be helpful when facing smaller issues, major decisions shouldn't necessarily be made using a shortcut approach to reach an inaccurate solution.

How are they related?

Both algorithms and heuristics are ways of solving problems, but they have different advantages and disadvantages. Algorithms are more reliable and accurate, but they can also be more complex and time-consuming. Heuristics are more flexible and efficient, but they can also be more error-prone and biased. We can combine algorithms and heuristics to create hybrid solutions that balance the trade-offs. For example, you can use a heuristic to narrow down the search space, and then apply an algorithm to find the best solution within that space.

Means-Ends Analysis

Means-end analysis is a problem-solving strategy that, to put it simply, helps you get from “point A” to “point B” by examining and coming up with solutions to obstacles.

Means-ends analysis is a strategy that involves breaking down a problem into smaller, manageable parts (means) and addressing each part to achieve the final goal (ends). It involves identifying the current state, the desired end state, and the steps needed to bridge the gap between the two.

Means-Ends Analysis Example 1

Imagine you want to plan a road trip from Trivandrum to Kashmir. Here is how you might use means-ends analysis.

1. Define the Goal:Drive from Trivandrum to Kashmir.
2. Analyze the Current State: You start in Trivandrum.
3. Identify the Differences: Distance between Trivandrum and Kashmir is approximately 3,700 kilometers.
4. Set Sub-Goals (Means):
   Fuel and Rest Stops: Where to stop for fuel and rest.
   Daily Driving Targets: Break the trip into daily segments, such as driving 500-600 km per day.
   Route Planning: Choose the most efficient and scenic route, considering highways, weather conditions, and places you want to visit.

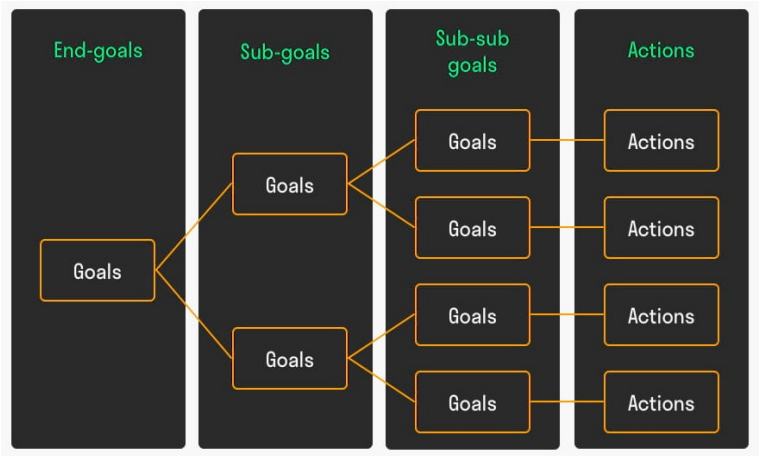
Means-Ends Analysis Example 1

5. Implement the Plan:
• Day 1: Drive from Trivandrum to Bangalore, Karnataka (approx. 720 km). Refuel in Madurai, Tamil Nadu. Overnight stay in Bangalore.
• Day 2: Drive from Bangalore to Hyderabad, Telangana (approx. 570 km). Refuel in Anantapur, Andhra Pradesh. Overnight stay in Hyderabad.
.....
• Day 8: Drive from Jammu to Srinagar, Kashmir (approx. 270 km).

6. Adjust as Needed: Throughout the trip, you may need to make adjustments based on traffic, road conditions, or personal preferences.

Means-Ends Analysis Example 2

Another Example, is if we want to prepare a chocolate ganache cake. We think of it as three sub-goals- cake , cream and the the chocolate ganache. Each has its on set of actions to prepare them. Then ultimately we combine these subgoals to reach the final product.


End-goals
Sub-goals
Sub-sub goals
Actions
Goals
Goals
Goals
Goals
Goals
Goals
Actions
Actions
Actions
Actions

Tower of Hanoi paradigm

Tower of Hanoi paradigm

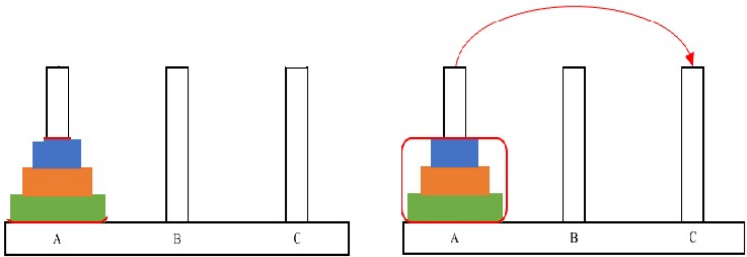
The actual Tower of Hanoi problem consists of three rods sitting vertically on a base with a number of disks of different sizes that can slide onto any rod. The puzzle starts with the disks in a neat stack in ascending order of size on one rod, the smallest at the top making a conical shape. The objective of the puzzle is to move the entire stack to another rod obeying the following rules:

1. Only one disk can be moved at a time.
2. Each move consists of taking the upper disk from one of the stacks and placing it on top of another stack or on an empty rod.
3. No larger disc may be placed on top of a smaller disk.

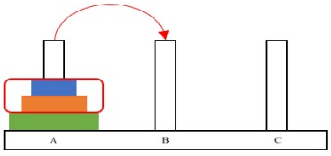
Tower of Hanoi

With 3 disks, the puzzle can be solved in 7 moves. The minimal moves required to solve a Tower of Hanoi puzzle is $2^n - 1$, where n is the number of disks. For example, if there were 14 disks in the tower, the minimum amount of moves that could be made to solve the puzzle would be $2^{14} - 1 =$ 16,383 moves. There are various ways of approaching the Tower of Hanoi or its related problems in addition to the approaches listed above including an iterative solution, recursive solution, non-recursive solution, a binary and Gray-code solutions, and graphical representations. We wl see MEA Solution.

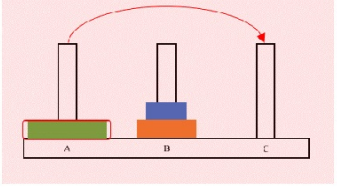
Tower of Hanoi



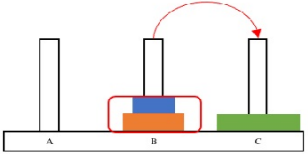
3AC DIVIDED AS SUBGOALS



2AB



1AC



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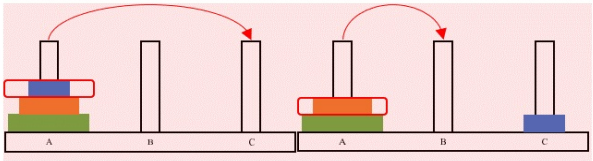
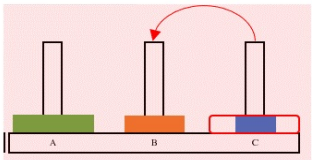
2AB DIVIDED AS SUBGOALS



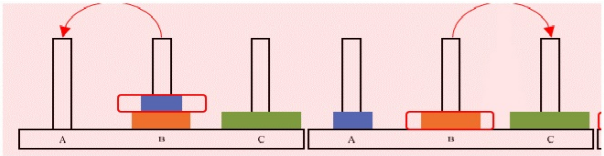
1AC

1AB



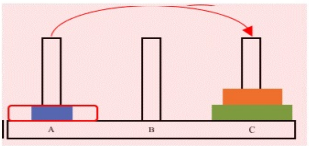
1CB

2BC DIVIDED AS SUBGOALS



1BA

1BC



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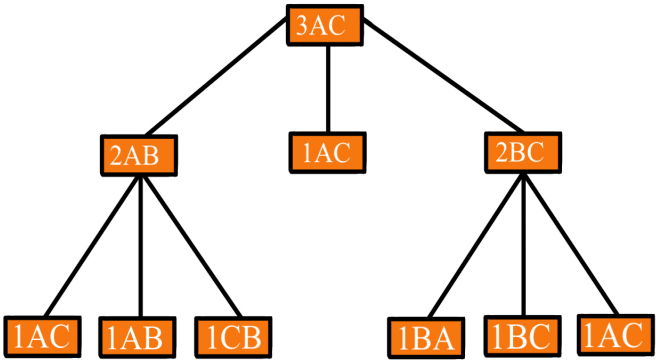
GRAPHICALLY

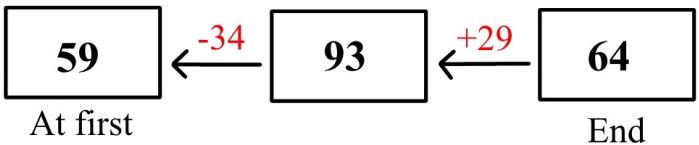


Working Backwards

Working Backwards is a problem-solving strategy in which you start with the end goal and work backward to figure out the steps needed to get there. In other words, instead of starting from the beginning and moving forward, you start from the end and move backward. This strategy is commonly used in math problems that ask you to find a starting value or figure out what happened before a given situation.

Working Backwards-Examples

Example 1: Sarah had some pens. She bought 34 pens. She then threw away 29 pens as they were spoilt. In the end, she had 64 pens. How many pens did Sarah have at first?



Working Backwards-Examples

Always remember when we work backwards, everything will be reversed, eg: instead of adding, we subtract.

We will start drawing the model from the end by drawing a box and label it “End”. Put the end amount “64” in the box.

Draw arrow to point to the left, draw another box. On top of the arrow write “+29” as “Sarah threw away 29 pens”. Instead of subtract, we need to add. In the box, write “93” (64+29=93).

Draw another arrow to point to the left, draw another box. On top of the arrow, write “-34” as Sarah bought 34 pens. Instead of adding, we need to subtract. In the box, write “59” (93-34=59). Label the box “At First” or “Before”.

Sarah had 59 pens at first.

Example 2:

Suppose you had to pick up your child from football practice at exactly 5:00 p.m. At what time should you leave? Well, let us say it takes 30 minutes to get to the ballpark. We would better leave a 5-minute safety valve. Okay, then we need to leave 35 minutes earlier, or not later than 4:25 p.m. Without even thinking about it, we were working backwards! Of course, this is a very simple example of this strategy.
This strategy is used when the end result is clear, but the beginning may be unclear due to some incidents that happened in between.

Summary of Problem Solving Strategies

Method	Description	Example
Trial and error	Continue trying different solutions until problem is solved	Restarting phone, turning off WiFi, turning off Bluetooth in order to determine why your phone is malfunctioning
Algorithm	Step-by-step problem-solving formula	Instruction manual for installing new software on your computer
Heuristic	General problem-solving framework	Working backwards; breaking a task into steps
Means-ends analysis	Analysing a problem at series of smaller steps to move closer to the goal	Envisioning the ultimate goal and determining the best strategy for attaining it in the current situation