PMDS508L - Python Programming
Module 1: Algorithmic Problem Solving

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Computational Thinking

Those who can imagine anything,
can create the impossible.

Alan Turing

- **Computational thinking** is an effective learning method that is used to solve complicated problems in a smart way.
- Those problems could be related to computer science or to everyday life.
- This method can be applied by humans, smart machines, or both.
- **Computational thinking** refers to the thought processes involved in expressing solutions as computational steps or algorithms that can be carried out by a computer.

Computational Thinking
Definition

- **Computational Thinking (CT)** is a problem-solving process.
- In our daily life we implement Computational Thinking knowingly or unknowingly. Such as
  - How we cook if we are hungry?
  - How do you plan your finances?
  - How do we improve ourselves at gym?
- In all the above activities we follow a step-by-step approach based on the priority.
- This step-by-step process involves computational thinking.

Computational Thinking Characteristics

- Formulating problems in a way that enables us to use a computer and other tools to help solve them.
- Logically organizing and analyzing data.
- Representing data through abstractions such as models and simulations.
- Automating solutions through algorithmic thinking (a series of ordered steps).
- Identifying, analyzing, and implementing possible solutions with the goal of achieving the most efficient and effective combination of steps and resources.
- Generalizing and transferring this problem solving process to a wide variety of problems.

Computational Thinking
Essential Dimensions

The Computational Thinking skills enhance a number of dispositions or attitudes.

- Confidence in dealing with complexity.
- Persistence in working with difficult problems.
- Tolerance for ambiguity.
- The ability to deal with open ended problems.
- The ability to communicate and work with others to achieve a common goal or solution.

A Puzzle

Tree

Fish

Bear

Bird

Flower

Dolphin

Tiger

Rooster

Computational Thinking - Illustration
Guess Which Organism I am Thinking Of?

Question 1: Does the organism has legs?

Question 1: Does the organism has legs?

YES

Question 1: Does the organism has legs?

YES

Bear

Bird

Tiger

Rooster

Question 1: Does the organism has legs?

YES

Bear

Bird

Tiger

Rooster

NO

Question 1: Does the organism has legs?

YES

Bear

Bird

Tiger

Rooster

NO

Tree

Fish

Flower

Dolphin

Question 2: Does the organism has wings/fins?

Organisms with Legs

Bear

Bird

Tiger

Rooster

Question 2: Does the organism has wings/fins?

Organisms with Legs

NO

Bear

Bird

Tiger

Rooster

Question 2: Does the organism has wings/fins?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO

Bear

Tiger

Question 2: Does the organism has wings/fins?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO

Bear

Tiger

YES

Question 2: Does the organism has wings/fins?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO

Bear

Tiger

YES

Bird

Rooster

Question 3: Does the organism has stripes?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO Wings

Bear

Tiger

Question 3: Does the organism has stripes?

YES

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO Wings

Bear

Tiger

Question 3: Does the organism has stripes?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO Wings

Bear

Tiger

YES

Tiger

Question 3: Does the organism has stripes?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO Wings

Bear

Tiger

YES

Tiger

NO

Question 3: Does the organism has stripes?

Organisms with Legs

Bear

Bird

Tiger

Rooster

NO Wings

Bear

Tiger

YES

Tiger

NO

Bear

Question 1: Does the organism has legs?

YES

Bear

Bird

Tiger

Rooster

NO

Tree

Fish

Flower

Dolphin

Question 2: Does the organism has wings/fins?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

Question 2: Does the organism has wings/fins?

Organisms with no Legs

NO

Tree

Fish

Flower

Dolphin

Question 2: Does the organism has wings/fins?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

NO

Tree

Flower

Question 2: Does the organism has wings/fins?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

NO

Tree

Flower

YES

Question 2: Does the organism has wings/fins?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

NO

Tree

Flower

YES

Fish

Dolphin

Question 3: Does the organism has stripes?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

With Fins

Fish

Dolphin

Question 3: Does the organism has stripes?

YES

Organisms with no Legs

Tree

Fish

Flower

Dolphin

With Fins

Fish

Dolphin

Question 3: Does the organism has stripes?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

With Fins

Fish

Dolphin

YES

Fish

Question 3: Does the organism has stripes?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

With Fins

Fish

Dolphin

YES

Fish

NO

Question 3: Does the organism has stripes?

Organisms with no Legs

Tree

Fish

Flower

Dolphin

With Fins

Fish

Dolphin

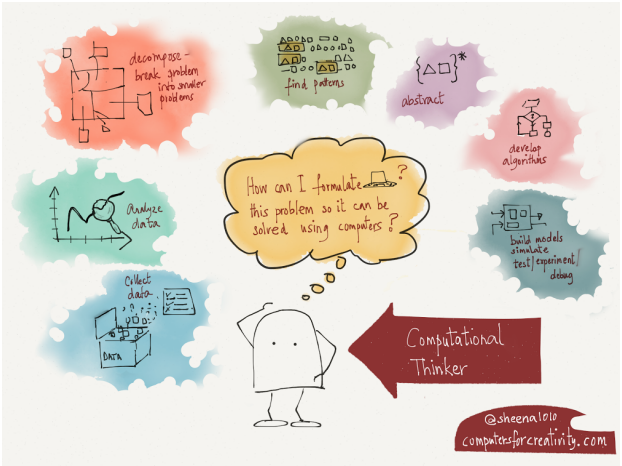
YES

Fish

NO

Dolphin

Computational Thinking Components



Computational Thinking Components

Computational Thinking is usually broken down into the following four components:

- **Decomposition**
- **Pattern Recognition**
- **Abstraction**
- **Algorithm Design**

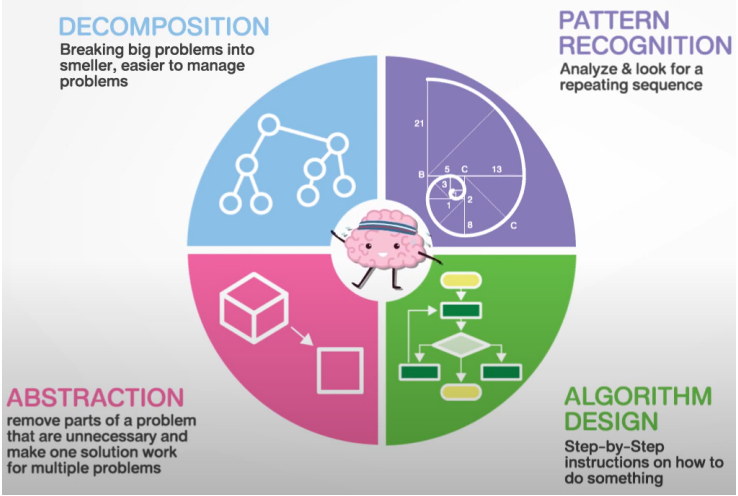
Computational Thinking Components

- **Decomposition:** Breaking down data, processes, or problems into smaller, manageable parts.
  Example in Literature: Break down the analysis of a poem into analysis of meter, rhyme, imagery, structure, tone, diction and meaning.
- **Pattern Recognition:** Observing patterns, trends, similarities, and differences across data.
  Example in Economics: Find cycle patterns in the rise and drop of the country's economy.

Computational Thinking Components

- **Abstraction:** Removing unnecessary information and identifying the general principles that generate these patterns.
  Example in Mathematics: Figure out the rules for factoring 2nd-order polynomials.
  Example in Chemistry: Determine the rules for chemical bonding and interactions.
- **Algorithm Design:** Developing the step-by-step instructions for solving this and similar problems.
  Culinary Arts: Write a recipe for others to use.

Computational Thinking Components



Computational Thinking vs Computer Science

Computational Thinking and Computer Science are different.

- Computational thinking is a problem-solving process that can be integrated across subject areas.
- Computer science is an academic discipline that involves the study of computation and its application using computers, and uses computational thinking as its primary problem-solving process.

Problem Solving: A Systematic Approach

- Problems are inherent in our day-to-day life.
- When a problem arises, we are ready to start analysing it and coming with a solution.
- As we are talking about computerising the solution, we need not only any solution but, one solution that is specially formed so that a computer could carry it out.
- So a question aries to all of us – “Where on earth do we start?”.

Problem Solving: A Systematic Approach

- Real-world problems tend to be big, complex things.
- Examining any non-trivial problem reveals all manner of hidden details, complex nuances and various facets to consider.
- It is impossible to understand the computational thinking without understanding the problem-solving skills and techniques.
- A step-by-step procedure for problem-solving would be an obvious benefit.
- Unfortunately, problem-solving is partly a *creative* process.
- Problem solving cannot be totally systematised, but strategies, heuristics and good practices exist to help us during the our creative endeavours.

Problem Solving: A Systematic Approach

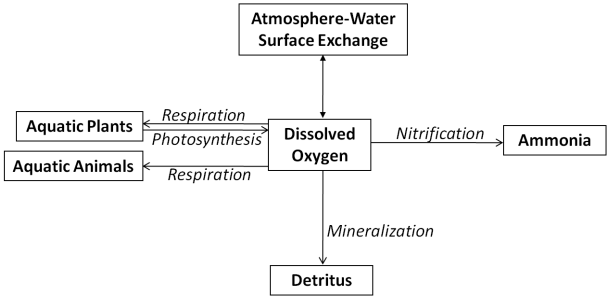
- Problem solving requires a systematic approach.
- An early example of systematic approach to general problem-solving was introduced by George Pölya, a Hungarian mathematician in a book called "*How to Solve It*" first published in 1973.
- Still, this book is in print after more than half-a-century and still abounds with relevant and helpful tips.
- The techniques described by Pölya guided many problem solvers down the years.
- Techniques to problem-solving inspired by the best traditions of mathematical and natural sciences.

Problem Solving: A Systematic Approach

- There are four steps in problem-solving process as per Pölya
  1. **Understand the problem:** This is also known as problem representation. Pölya encourages solvers to draw diagrams and graphs if necessary.
  2. **Devise a plan:** In this step the solvers find a connection between the data and the unknown by trying to find similar problems that they have encountered before or finding auxiliary problems if a direct connection cannot be found. Ultimate goal of this step is to come up with a plan to the solution.
  3. **Carry out the plan:** In this step solvers implement their solution also check that each step is correct.
  4. **Evaluate the result and Look backward:** Finally, solvers examine their solution for correctness and understanding. If any thing is not according to the plan the go back and redo the process.

Problem Solving: A Systematic Approach

Example: Suppose we wish to model the Dissolved Oxygen in a Lake. Then we should have proper understanding of various processes that influence the Oxygen levels in water viz., Oxygen exchange between air and water, Oxygen generation and consumption by Phytoplankton, Oxygen consumption by Fish etc., Nitrification process and finally mineralisation process of dead animals. This can be represented as a pictorial way as below:

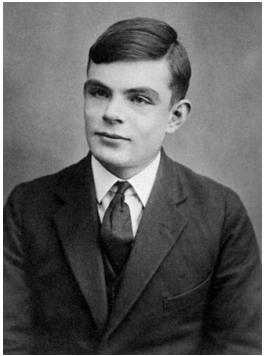


Problem Solving: Present Day Approach

- The present day computer scientists are employing the below four strategies that are the core of this modern style of problem solving:
  1. Problem definition
  2. Logical reasoning
  3. Decomposition
  4. Abstraction

Alan Turing

- **Alan Mathison Turing** (23 June 1912 – 7 June 1954) was an English mathematician, computer scientist, logician, cryptanalyst, philosopher, and theoretical biologist.
- Turing was highly influential in the development of *theoretical computer science*, providing a formalisation of the concepts of algorithm and computation with the Turing machine, which can be considered a model of a general-purpose computer.
- He is known as the father of modern computing and artificial intelligence.



Turing at the Age 16.

https://en.wikipedia.org/wiki/Alan_Turing

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