Computational Thinking

Unit Contents

- What is computational thinking?
- Computational thinking approaches
- Information and Data
- Data Types and Encoding

Unit Outcomes

1. Define computational thinking.
2. Compare information and data.
3. Discuss the importance of data types and encoding.

Computational Thinking

Computational thinking is defined as a process or thought or strategy to solve complex problems based on the approaches from computer science.

Computational Thinking

- The various fields such as mathematics, science and engineering, natural sciences, social sciences, and day-to-day life situations are using techniques based on **computational thinking**.
- With the help of **computational thinking**, people can use structured methods for solving a problem.

Computational Thinking - Approaches

- Problem Decomposition
- Pattern Recognition
- Abstraction
- Algorithm
- Automation
- Evaluation

Problem Decomposition

- This method is also known as Divide and Conquer.
- A large problem is divided into smaller parts.
- The division is based on the hierarchy.
- The connections or interfaces among the parts are identified.
- This method makes the job of solving the problem easier and each subproblem can be tackled individually with more focus.

Pattern Recognition

- In this method, the emphasis is on recognizing similar features, patterns, or parts in each problem or data.
- The similarity of the data can be recognized, and the developed programs can be reused.
- The solution to the problem can be more efficient due to the identification of similar structures, data, and processes.

Abstraction

- Highlighting important features and hiding irrelevant details to focus on the basic problem.

- The problem can be expressed clearly, and unnecessary details or irrelevant information can be ignored.

- Consider a person selling a car, the details such as make, mileage, safety features, and cost are explained to the customer.

- General solutions can be formed using abstraction.

Algorithm

- A given problem is solved using a step-by-step procedure by considering different situations and constraints using algorithms.

- An algorithmic approach is helpful in expressing:
  - Necessary inputs
  - Sequence of operations
  - Desired output

Automation

- Using technology for routine tasks that are done repetitively is known as automation.
- With the help of automation, computer programs are used for mundane tasks with which the developer can focus more on core tasks.
- Automation can be visualized with simulation.
- Simulation is a model that gives a virtual representation of the real world.

Evaluation

- **Evaluation** is a method of judging the effect and productivity of the solution.

- After **evaluation,** if necessary, the solution is optimized or refined.

- The optimized solutions are more robust and improve problem-solving skills.

Summary

- **Computational thinking** approaches are used in combination with each other in various contexts.
- **Computational thinking** helps to understand what the problem is and develop possible solutions.
- The solutions can be presented in a way that a **computer, a human, or both**, can understand.
- Example: chess strategy, algorithms for weather predictions, making and reading maps, and organizing a daily planner.

END

History of Devices Towards Computers

Computer

- **Computational thinking** helps people to think critically and logically using Computers.

- A **computer** is an electronic machine that collects information, stores it, processes it according to user instructions, and then returns the result.

- A **computer** is a programmable electronic device that performs arithmetic and logical operations automatically using a set of instructions provided by the user.

Computing Devices

- **Abacus:** Chinese abacus was once a very commonly used computing and numeric tool in East Asia, mainly in China.
- **Napier Bones:** This device was made up of small rectangular sticks with numbers and lines used for multiplication, division, square roots, etc.
- **Pascaline:** Pascaline was the first mechanical and automated calculator. It was a wooden box with gears and wheels.
- **Gottfried Leibniz** invented devices like huge mechanical machines to perform arithmetic operations such as addition, subtraction, multiplication, or division. This improved the human capacity to speed up the calculations.

Computing Devices

- Some devices were also used for doing operations other than calculations.
- The **Antikythera** mechanism is a device invented by Greek scientists that was made up of 30 interconnected gears of metal brass of different dimensions.
- The **Antikythera** device could find the locations of the sun, moon, and other planets.
- The device was called a computer of the **first century BC.**
- These devices were led to a term **Computer.**

Modern Computer

- The first modern computer has three characteristics as given below.
- 1. Electronic device
- 2. Digital
- 3. The stored program concept

History of Computers

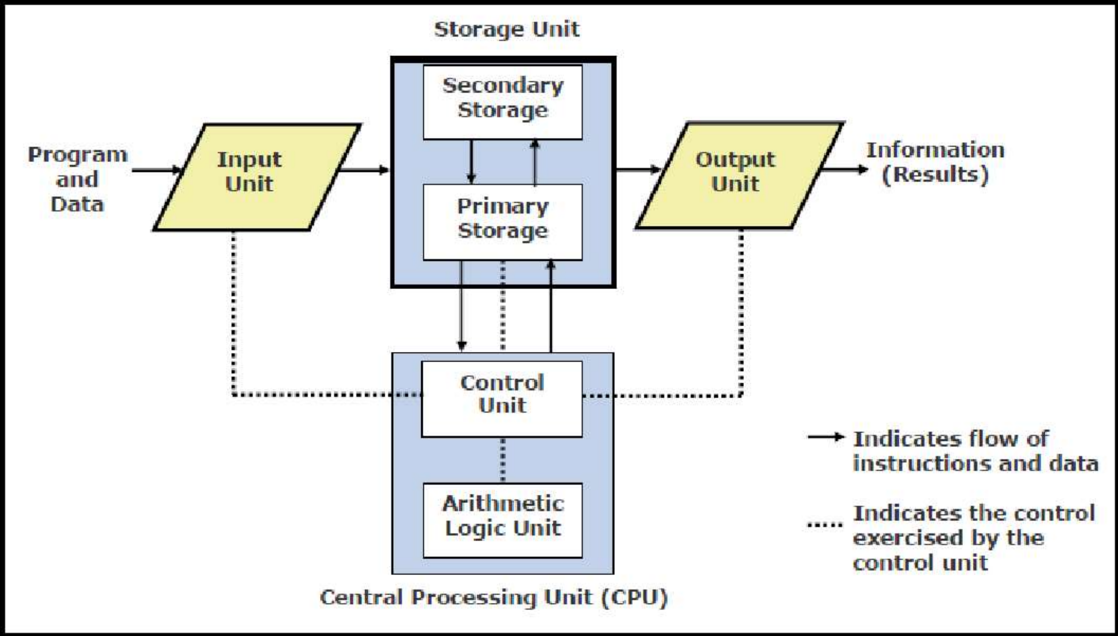
- The Analytical Engine: Charles Babbage.
- In 1890, a scientist named Herman Hollerith invented a calculating device for recording the US census that ran on electricity.
- In 1924, the IBM company developed a mechanical tabulating machine.
- In 1930, the analog device was invented by Vannevar Bush.
- This machine has vacuum tubes to switch electrical signals to perform calculations in a few minutes. This was known as Differential Analyzer.

History of Computers

- In 1946, the Electronic Numerical Integrator and Computer (ENIAC) was developed as the first electronic computer by two researchers in the USA.
- ENIAC is considered the first modern computer.
- There are five generations of computers with ENIAC as the first-generation computer.

  - First Generation (1940 to 1956): Using Vacuum Tubes
  - Second Generation (1956 to 1963): Using Transistors
  - Third Generation (1964 to 1971): Using Integrated Circuits
  - Fourth Generation (1971 to present): Using Microprocessors
  - Fifth Generation (Present and Next): Using Artificial Intelligence

Block Diagram of a Computer



Modern Computer

- A computer is an electronic device that can be programmed to accept data (input), process it, and generate results (output).
- A computer along with additional hardware and software together is called a computer system.
- A computer system primarily comprises a central processing unit (CPU), memory, input/output devices, and storage devices.
- All these components function together as a single unit to deliver the desired output.
- A computer system comes in various forms and sizes. It can vary from a high-end server to a personal desktop, laptop, tablet computer, or smartphone.

Summary

Basic Terms Related to Computers

- Vacuum Tube
- Transistor
- Integrated Circuit (IC)
- Microprocessors
- CPU
- Magnetic Drum
- Magnetic Core
- Machine Language
- Memory
- Artificial Intelligence

Summary

Generations of Computers:

- First Generation Computers (1940-1956)
- Second Generation Computers (1956-1963)
- Third Generation Computers (1964-1971)
- Fourth Generation Computers (1971-Present)
- Fifth Generation Computers (Present and Beyond)

END

Software

Need of Software

- The hardware devices are used to perform computations with suitable configurations.
- The devices cannot be used efficiently for programming.
- For every new problem, the previous configuration gets erased.
- It is important to load a copy of a program that contains a set of instructions, separated from the hardware.

Need of Software

- Devices before the invention of the computer were not truly programmable.
- A concept of a stored program was invented to instruct the computer to do the assigned task.

Software

- The first programmable machine was developed for weaving cloth called the Jacquard loom in 1805.
- The programmable loom was manufactured that takes a card with punched holes.
- Punching cards were like programs.
- In 1843, a mathematician named Charles Babbage built a mechanical calculator performing calculations with more advanced logarithmic and trigonometric calculations.
- This was modified in the analytical engine to include programmability.

Software

- Software refers to the computer programs and related documentation developed for a specific client or for a general market.
- The software consists of computer programs, data structures, and documentation.
- Examples of Software: Online Reservation System, Windows Operating System, VLC Movie Player, Firefox, Google Chrome, etc.

Types of Software

- System Software: Operating System, Text Editors, Compilers
- Programming Software: Tools for writing computer programs, such as Java, Python, C, C++, etc.
- Application Software: Software for a particular task such as accounting, data processing, games, etc.

Types of Software

- Scientific / Engineering Software
- Embedded Software
- Application Software
- Web application
- Artificial intelligence

END

Information and Data

Information and Data

- Personal computers were extremely popular in the 1970s.
- In the 1990s, the Internet was developed which brought data and computation together.
- The terms information and data were introduced at this time.
- Data is a collection of facts.
- Information puts the facts in some context and gives meaning.
- E.g., 1,2,3,4…. Is data but these numbers stored in Roll No are known as information.

Data and Information

Data	Information
Data is a raw, unorganized, collection of facts.	Information is processed and it is knowledge of facts. Information is in a structured form.
Data includes numbers, characters, alphabets, lines of text, words, etc.	Information can refer to records, organized data files, tables, databases, etc.
In computer terms, data is an input.	Information is an output that is an outcome of the computer processing of data
Data cannot be useful in its original form	Information can be used in its original form.

Data to Information

- Converting data into information is a challenging task.
- For example, storing paintings, audio, or video files, texts, numbers, addresses, and phone numbers on cellphones, etc. need to be stored as information.
- This is done using encoding. Some of the important concepts in the conversion of information and data are:

•Encoding of data refers to the task of converting data into a form that is suitable for processing.

•In electronic terms, there are two types of data, analog and digital.

•Continuous data is encoded as analog and discrete data is called digital.

•Digital data is a set of discrete data values or possible data values.

Digital Data

- In digital form, the smallest unit of data is known as a bit or binary digit.
- A bit can take two forms 1 (ON) or 0 (OFF).
- The audio/video, images, text, and numbers can be encoded as a sequence of bits.

Number	Bit String
1	1
2	10
3	110
4	100
5	101
6	110
7	111
8	1000
9	1001
10	1010

Digital Data Prefix

Length of Bit String	Number of Patterns
1	$2^1 = 2$
2	$2^2 = 4$
3	$2^3 = 8$
4	$2^4 = 16$
5	$2^5 = 32$
8	$2^8 = 256$
N	2^N

Prefix	Symbol	Power of 2	Decimal
Kilo	K	2^{10}	$\sim 10^3$
Mega	M	2^{20}	$\sim 10^6$
Giga	G	2^{30}	$\sim 10^9$
Tera	T	2^{40}	$\sim 10^{12}$
Peta	P	2^{50}	$\sim 10^{15}$

Prefix and Data Capacity

Type of Information	Data Capacity (Bytes)
keyboard symbol (letter)	1 B
10 page paper	40 KB
five minute MP3 audio recording	5 MB
high resolution digital picture	5 MB
CD audio disk	800 MB
DVD	8.5 GB
all of Wikipedia	6 TB*

Encoding of Different Data Types

- Different kinds of data are represented using a sequence of bits.
- The representation of various data types is explained with an example.

The types of data are given as:

1) Number
2) Text
3) Images
4) Color
5) Sound

Numbers

- Numeric data can be represented using different number systems such as Tally, Roman, decimal, binary, octal, hexadecimal, etc.
- The different representation of the number of ‘5’ is shown below

Number System

Base N
N Digits: 0, 1, 2, 3, 4, 5, …, N-1
Example: 1045N
Positional Number System

Digit d_o is the least significant digit (LSD).
Digit dn-1 is the most significant digit (MSD).

Base 10
Ten Digits: 0, 1, 2, 3, 4, 5, 6, 7, 8, 9
Example: 104510
Positional Number System

Binary Number System

Base 2
Two Digits: 0, 1
Example: 1010110 in Binary
Positional Number System

Binary Digits are called Bits.
Bit b_o is the least significant bit (LSB).
Bit b_{n-1} is the most significant bit (MSB).

Binary	Decimal
0000	0
0001	1
0010	2
0011	3
0100	4
0101	5
0110	6
0111	7
1000	8
1001	9
1010	10

Hexadecimal Number System

Base 16

Sixteen Digits: 0,1,2,3,4,5,6,7,8,9, A, B, C, D, E, F

Example: EF5616

Positional Number System

Exercise 1

Convert a decimal number 25 to binary.

Divisor	Dividend	Remainder
2	25	1
2	12	0
2	6	0
2	3	1
	1	
	$(25)_{10}$	$(11001)_2$

Exercise 2

Convert $(11001)_2$ to decimal form. The stepwise description is as follows:

- Step 1: Write down the binary number:
- Step 2: Multiply each digit of the binary number by the corresponding power of two:
- Step 3: Solve the powers.
- Step 4: Add up the numbers after solving the power values.

$=1x2^4 + 1x2^3 + 0x2^2 + 0x2^1 + 1x2^0$

$=1x16 + 1x8 + 0x4 + 0x2 + 1x1$

$= 16 + 8 + 0 + 0 + 1$

$= 25$

Exercise 3

Convert a decimal number 120 to hexadecimal form

Step 1: Divide $(120)_{10}$ successively by 16 until the quotient is 0:

120/16 = 7, the remainder is 8

7/16 = 0, the remainder is 7

Step 2: Read from the bottom (MSB) to the top (LSB) as 78.

So, 78 is the hexadecimal equivalent of the decimal number 120 (Answer).

Exercise 4

Convert a hex number (A1)16 to decimal.

Ax161 + 1x160

10x16 + 1x1 = (161)10

This can be proved by converting decimal (161)10 to Hex.

61/16 = 10, the remainder is 1

10/16 = 0, the remainder is 10

Read from the bottom (MSB) to the top (LSB) as A1.

So, A1 is the hexadecimal equivalent of the decimal number 161.

END

Information and Data

Text Data

ASCII Character Set

0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
20	21	22	23	24	25	26	27	28	29	30	31	32	! 33	" 34	# 35	$ 36	% 37	& 38	’ 39
(40	) 41	* 42	+ 43	, 44	- 45	. 46	/ 47	0 48	1 49	2 50	3 51	4 52	5 53	6 54	7 55	8 56	9 57	: 58	; 59
< 60	= 61	> 62	? 63	@ 64	A 65	B 66	C 67	D 68	E 69	F 70	G 71	H 72	I 73	J 74	K 75	L 76	M 77	N 78	O 79
P 80	Q 81	R 82	S 83	T 84	U 85	V 86	W 87	X 88	Y 89	Z 90	[91	\ 92	] 93	^ 94	_ 95	` 96	a 97	b 98	c 99
d 100	e 101	f 102	g 103	h 104	i 105	j 106	k 107	l 108	m 109	n 110	o 111	p 112	q 113	r 114	s 115	t 116	u 117	v 118	w 119
x 120	y 121	z 122	{ 123	| 124	} 125	~ 126	127	128	129	130	131	132	133	134	135	136	137	138	139

Colours in Data

Three fundamental colors perceived by the human eye, these are namely red (R), green (G), and blue (B), commonly known as RGB

Color	Name	Bits red green blue	Decimal
	red	111111110000000000000000	(255,0,0)
	green	000000001111111100000000	(0,255,0)
	yellow	111111111111111100000000	(255,255,0)

Pictures

- The picture can be formed using a two-dimensional grid of colors.
- Each element of the grid is called a pixel.
- A pixel stands for picture element representation of a tiny rectangle of a single color.
- Color is encoded as a 24-bit string; thus, the picture is considered as an order of 24.
- The images of high definition (HD) are represented using the resolution: 1920 X 1080 = 2,073,00 pixels.

Sound

- The audio data in a computer is generated using sound waves that propagate through the air.
- A microphone converts the waveform into an analog electric signal.
- These signals are measured and sampled to produce a digital encoding.
- Sampling is a process where the strength of a changing signal is measured at regular time intervals and those measurements are then recorded.
- Sound wave is converted into a sequence of numeric values. The unit of measurement for sound is Hertz (Hz). The average person can hear sound waves 20 Hz up through about 20,000 Hz or 20 kHz.

Data Compression

- Data compression is a method with which the encoding is done with fewer bits.
- The compressed data can be transferred on a smaller hard disk or sent off the Internet.
- Compression is time-consuming and it adds to the overload.
- Run-Length Encoding is one of the simplest types of compression techniques that can be used on images and even text.