From Chaos to Order: The Art of Data Structures & Algorithms

Dr. Zubair Ahmad

About me!

Zubair Ahmad

Education

- Ph.D. in Computer Science – University of Venice Italy & CISPA Helmholtz Center for Information Security Germany 2024

- European Parliament – EU AI Act 2023
- OPLSS Summer School Uni of Oregon and Boston Uni USA 2021

Research Interests

- Web Security and Privacy
- Data Privacy and Protection
- Internet and Web Measurements
- EU Compliance regulations, GDPR
- Internet of Things

More about me -->https://zahmaad.github.io/

Schedule

- **When?**

  - Will Share soon

- **Where?**

  - Here!
  - CS LH3

- **What?**

  - Lecturers and exercises
  - Quizzes/ Projects
  - Mid/Final Exams

- **Attendance?**

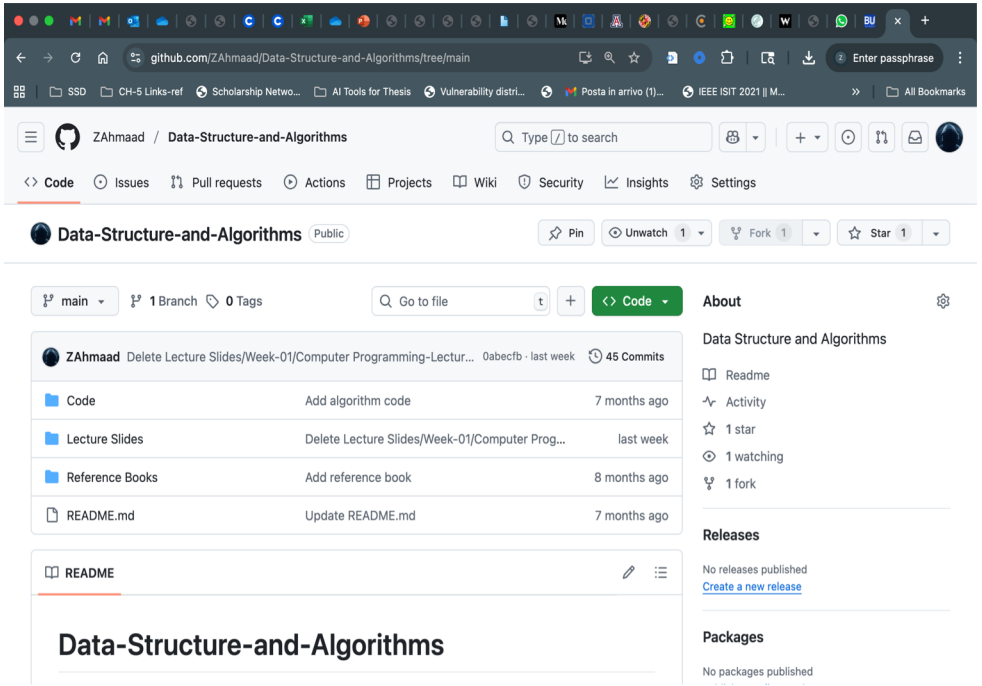
  - Active Attendance
  - **Dead Bodies.**
  - **Active Minds**
  - Mobiles in hands -> Mark as absent
  - No entry -> Fives minutes after the class starts
  - 80% mandatory

Course Webpage

- Lectures/ Slides
- Books
- Project
- News

- GitHub
- Overleaf

Project



https://github.com/ZAhmaad/Data-Structure-and-Algorithms

Reference Books

Introduction to Algorithms: A Comprehensive Guide for Beginners: Unlocking Computational Thinking by Cuantum Technologies
Introduction to Algorithms, Thomas H. Cormen et al,4th Edition, 2022
Data Structures using C++ By D.S. Malik, 2012
Introduction.to.Algorithms.4th.Leiserson.Stein.Rivest.Cormen.MIT.Press.9780262046305.EBooksWorld.ir.
Data Structures and Algorithm Analysis in C++ by Mark Allen Weiss, Fourth edition
Data Structures and Algorithms in C++ by Adam Drozdek

Course Learning Outcomes

Sr. No	Course Learning Outcomes+	Graduate Attributes (GAs)	Bloom's Taxonomy level (Cognitive domain)
CLO 1	Utilize the basic techniques of data structure/algorithm analysis	GA-2 (Knowledge for Solving Computing Problems)	C 2 (Understanding)
CLO 2	Apply the primitive data structures to design solutions for the computational problems	GA-2 (Knowledge for Solving Computing Problems)	C 3 (Applying)
CLO 3	Analyzing problems and writing program solutions to problems using the algorithmic techniques using a variety of data structures and techniques	GA-4 (Design/ Development of Solutions)	C3 (Applying)

Course Assessment

Assessment Items	Percentage
Quizzes	20%
Project	10%
Midterm Exam	30%
Final Exam	40%

Why this course?

- Improves Problem-Solving Skills
- Builds Efficient Software
- Critical for Technical Interviews
- Optimizes Resource Usage
- Universal Applicability
- Essential for Advanced Computer Science Topics

What We will learn?

1st Week

- Fundamentals of data structures
- An overview of computer programming
- Data types, abstract data types
- Programming background

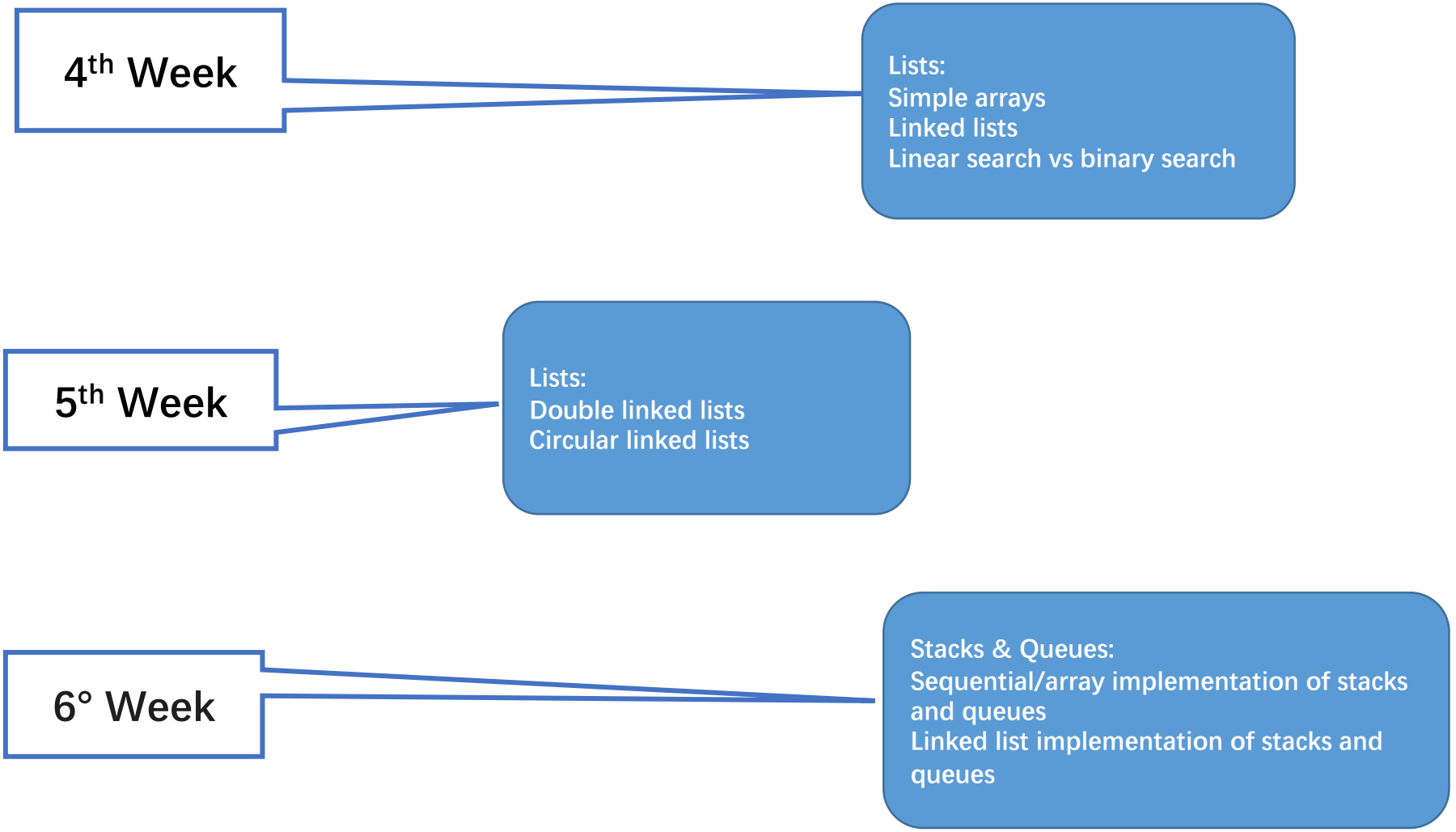
2nd Week

Review of pointers:Pointers and arrays
Pointer indirections
Structures and pointers
Passing pointer arguments to a function and returning pointers from a function

3° Week

Computational complexity of algorithms and their time-space analysis:Running time calculations
Asymptotic notations for algorithmic complexity analysis

What We will learn?



What We will learn?

7th Week

- Arithmetic expressions, polish notation
- Recursion:
- Recursive implementation of stacks
- Recursive implementation of queues

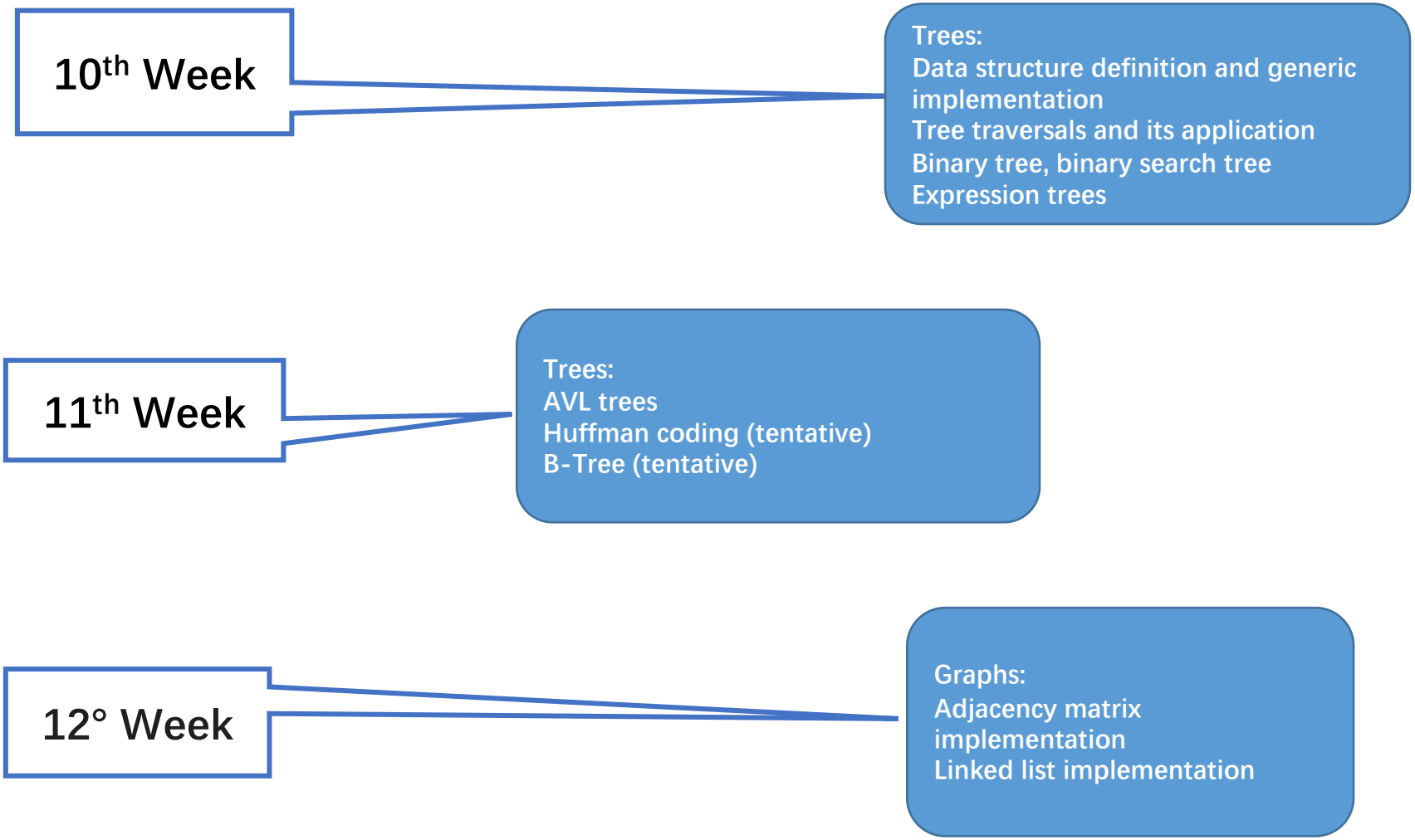
8th Week

- Sorting:
- Bubble sort
- Insertion sort
- Selection sort

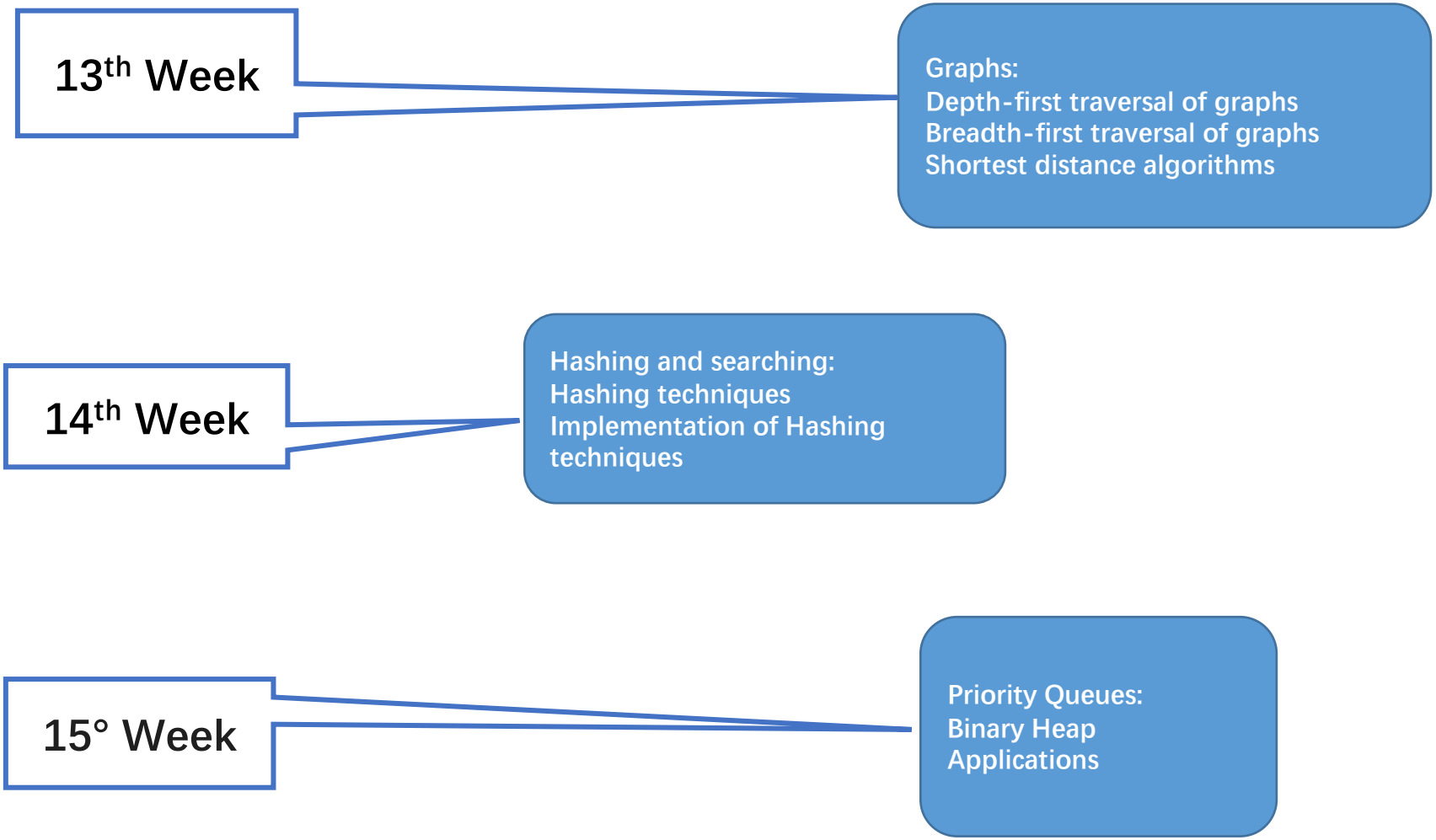
9° Week

- Sorting:
- Merge sort
- Quick sort
- Counting Sort & Radix sort
- Heap sort (tentative)

What We will learn?



What We will learn?



Data = Information?

Is it same or different?
Example??

Information
Any Knowledge in the basic form that can be communicated including abstract ideas and concepts

Data:
In a form that a computer can use

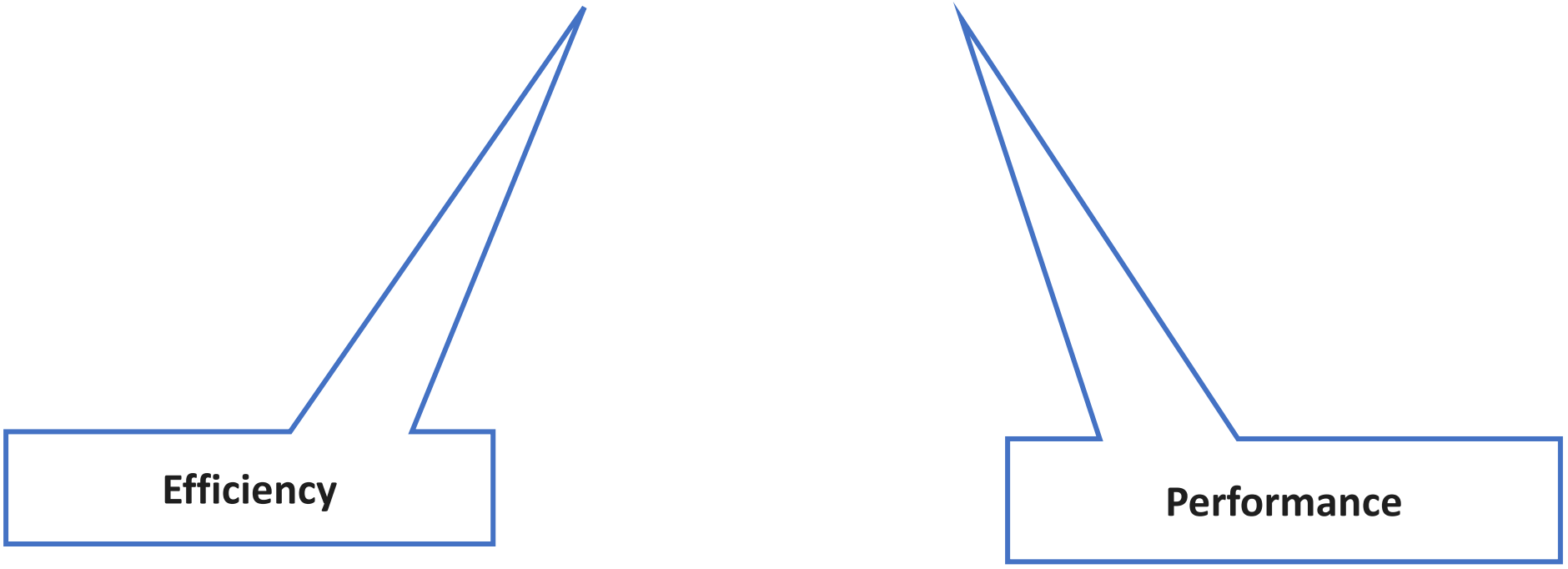
London is located in UK

GPS Coordinates
(51.5074° N, 0.1278° W)

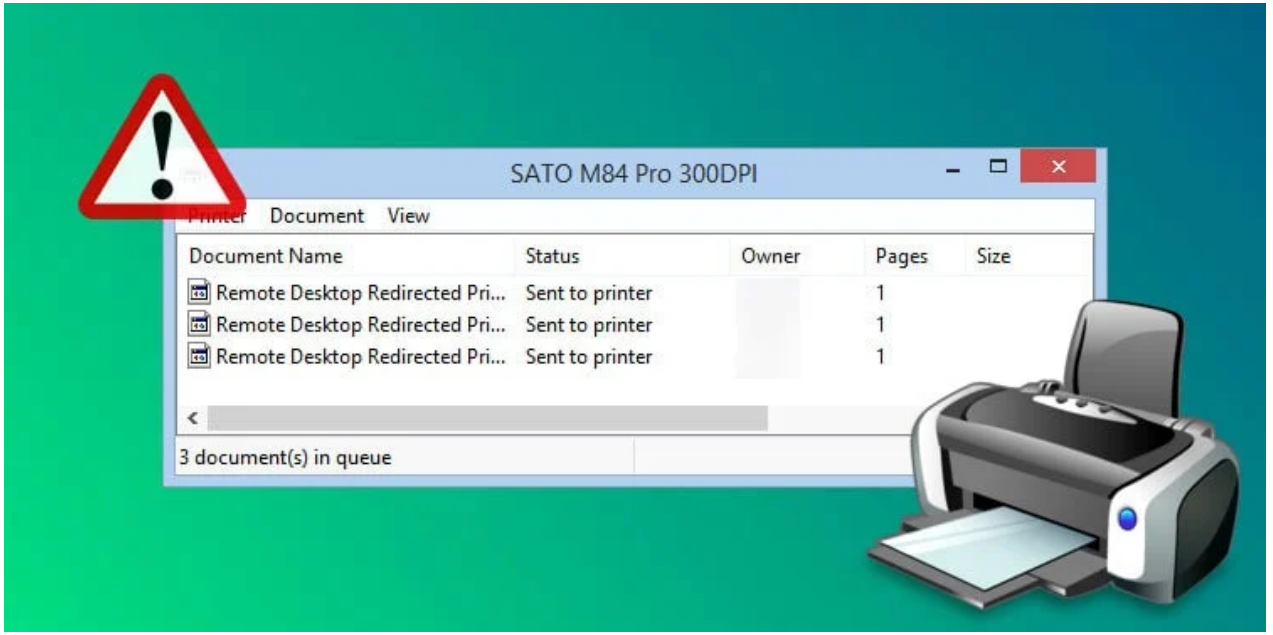
Why we need Data Structure?

Big amount of Data store in a rough way leads to complications and poor performance

Data Structure is how data can be stored in different structures



Data Structures – Real Life Scenarios

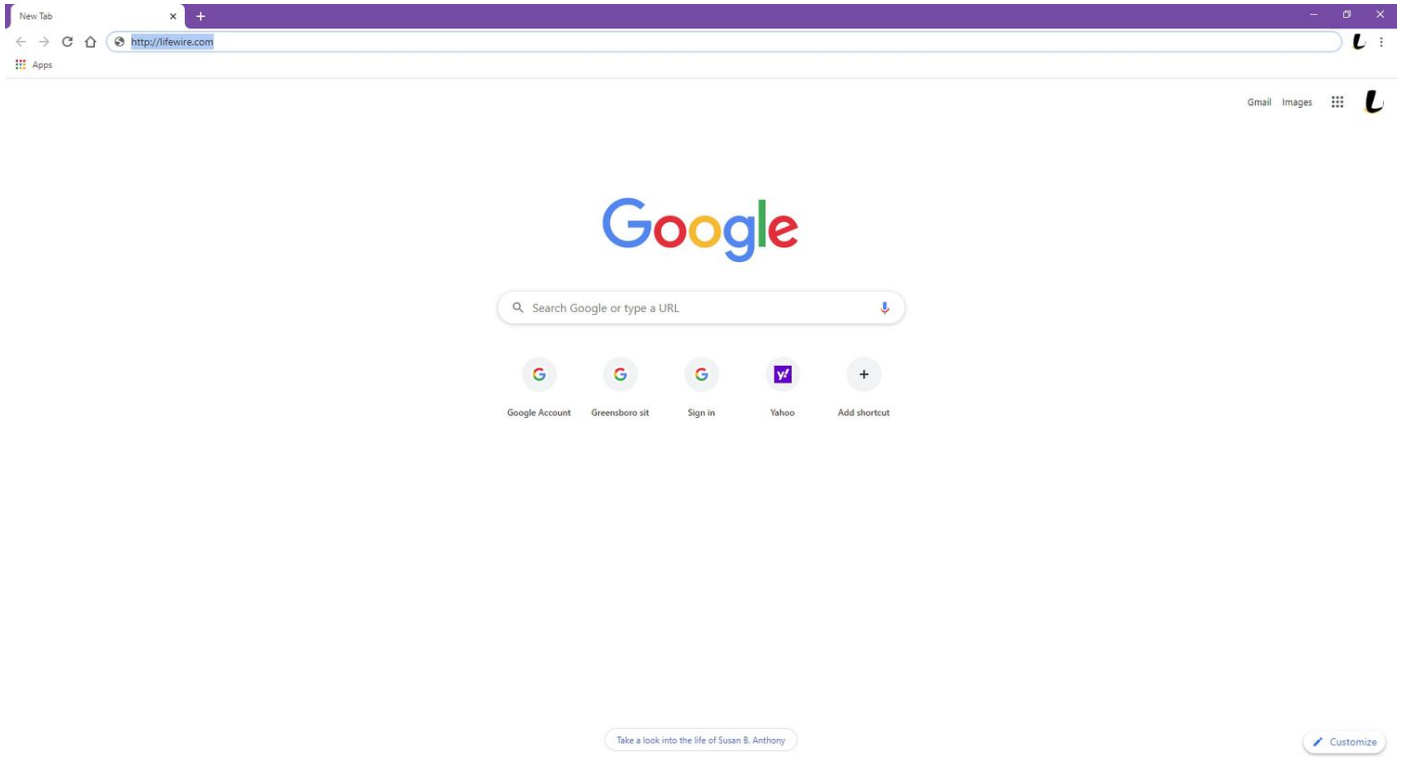


Printing Jobs:
The first document sent to the printer is processed first (FIFO).

QUEUE?

Any other example? → Customer Support Systems

Data Structures – Real Life Scenarios



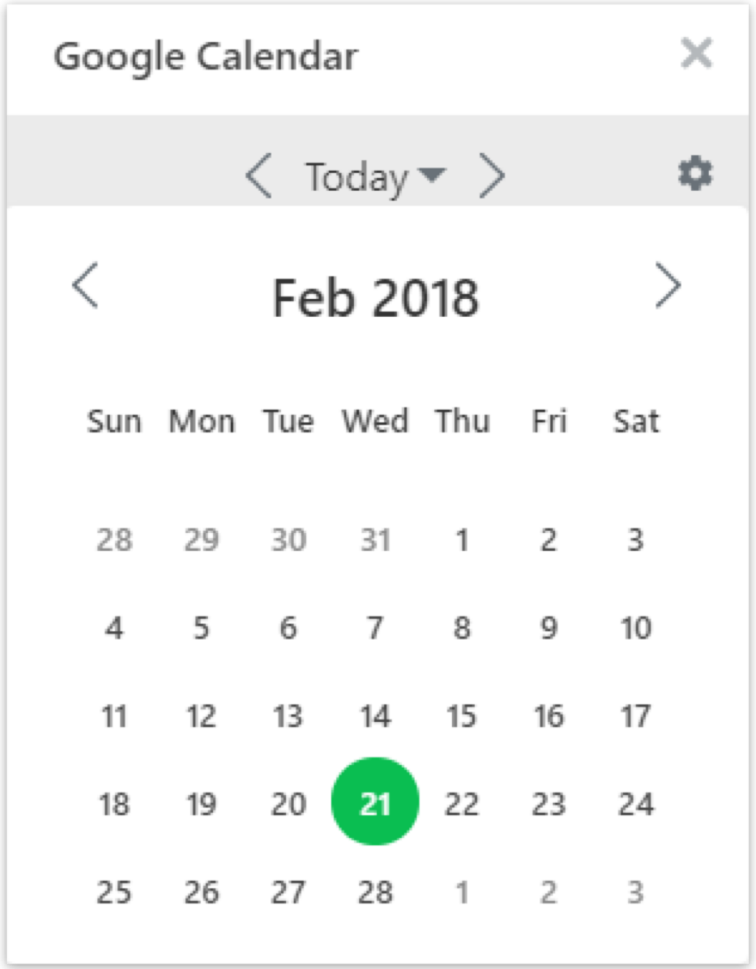
Web Browser Back Button

When you visit pages, the browser stores URLs in a stack. The most recently visited page is at the top, and pressing "back" pops it off

Stack

Any other example? → Text Editors

Data Structures – Real Life Scenarios



Calendar App

Days of the week or months of the year are stored in arrays for quick access.

Array

Any other example?

Data Structures – Real Life Scenarios

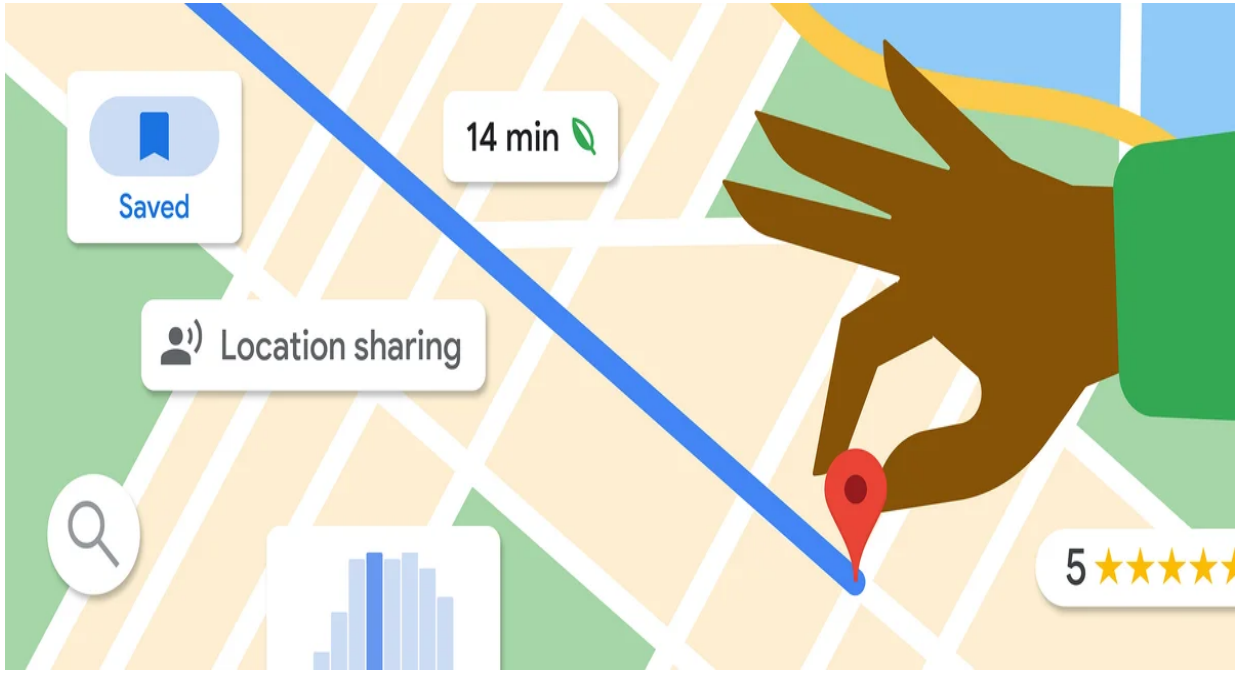
File System

Your computer's directory structure is a tree. Each folder (node) can contain files or subfolders (child nodes)

Tree

Any other example? → Organizational Hierarchy

Data Structures – Real Life Scenarios



Google Maps or GPS Navigation:

Locations are represented as nodes, and roads are edges connecting them. Algorithms like Dijkstra's are used to find the shortest path

Graph

Any other example? → Social Networks

Data Structures – Real Life Scenarios

Airline Route Maps

Airports are nodes, and flights between them are edges. Weights represent distances or travel costs.

Graph with Weighted Edges

Any other example? → E-commerce Recommendation Systems

Data Structures – Real Life Scenarios

Autocomplete in Search Engines

Stores prefixes of words, enabling fast suggestions as you type.
Example: Typing "san f" shows results like "san Francisco weather", etc

Trie

Any other example? → Spell Checkers

Data Structures – Real Life Scenarios

Emergency Services

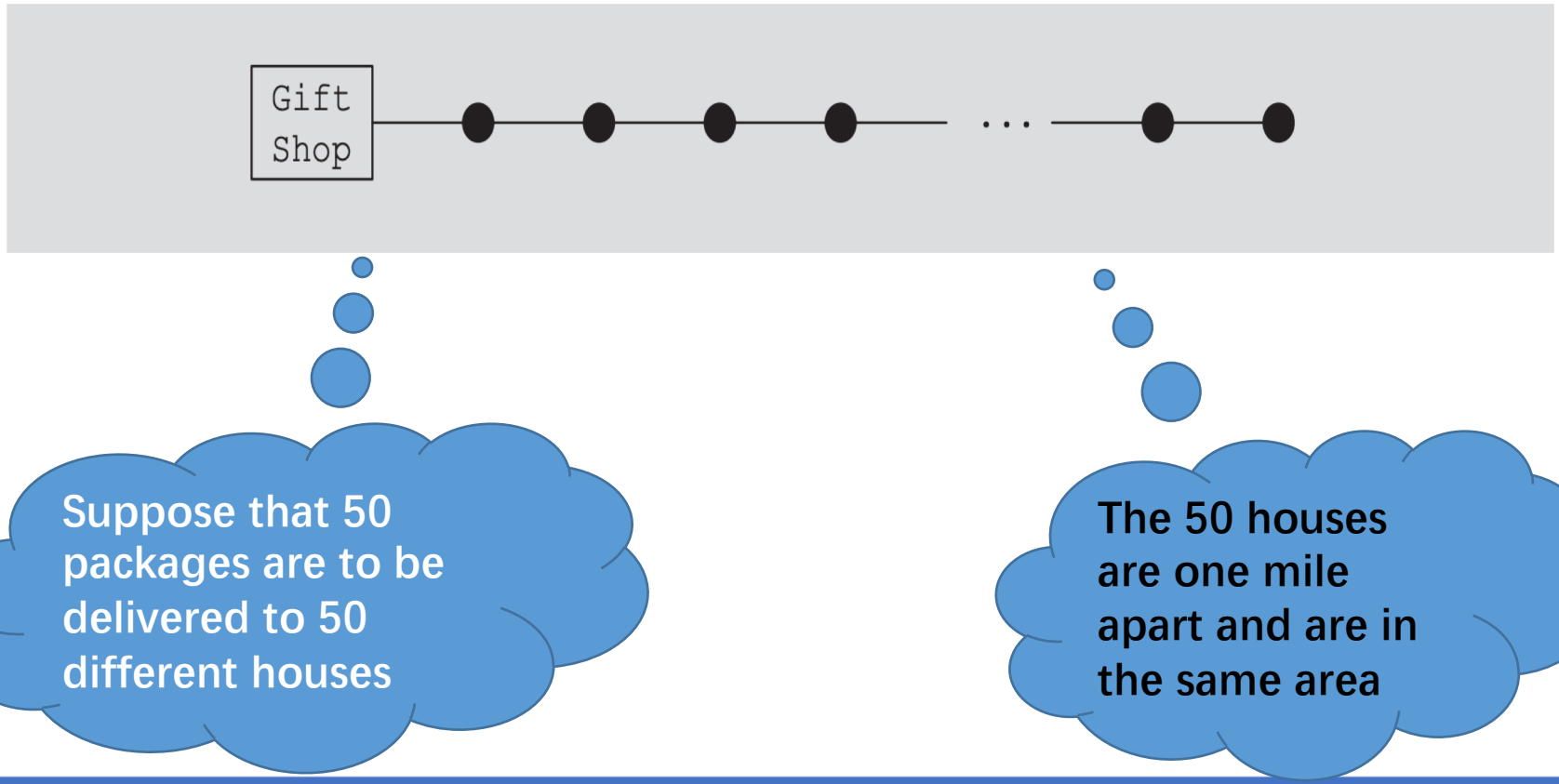
Tasks with the highest priority (e.g., critical patients) are processed first

Heap

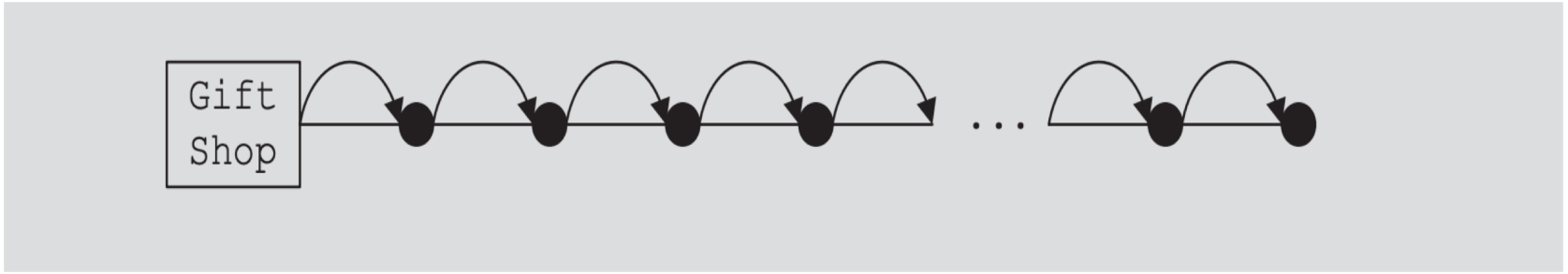
Any other example? → Job Scheduling in Operating Systems

Algorithm Analysis?

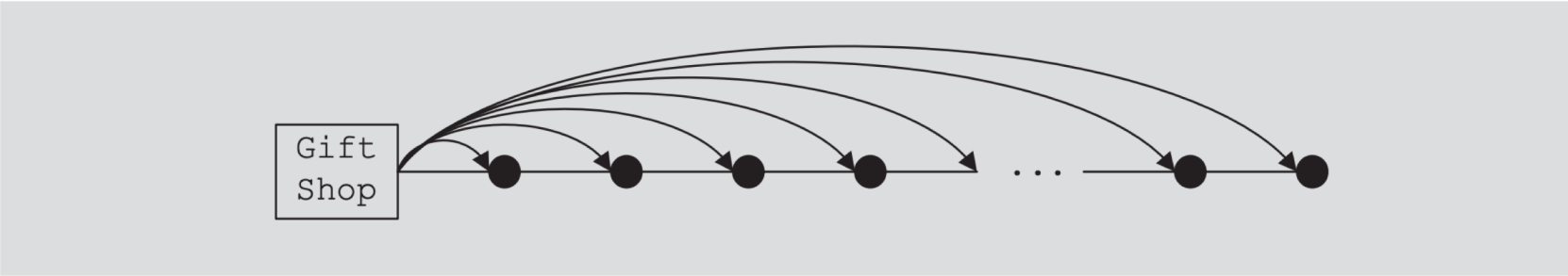
Set of step-by-step instructions to solve a given problem or achieve a specific goal



Algorithm Analysis?



Algorithm Analysis?



Focus on the number of operations, not on the actual computer time to execute the algorithm

By understanding DSA, you can:

- Decide which data structure or algorithm is best for a given situation.
- Make programs that run faster or use less memory.
- Understand how to approach complex problems and solve them in a systematic way.

Application of DSA in Cyber Security

"Cybersecurity isnt just about firewalls and passwords. Its powered by the same algorithms and data structures we are learning in this course. From detecting malware with pattern-matching algorithms to securing transactions with Merkle Trees, **DSA is the backbone of Cyber Security**."

Application of DSA in Cyber Security

- Cryptography – Efficient algorithms for encryption
- Hashing – Password storage, digital signatures, integrity checks
- Intrusion Detection – Pattern matching
- Network Security – IP filtering using trees
- Access Control – Graph structures for role-based security
- Forensics – Searching logs with trees and hash maps
- Blockchain – Trees for secure data verification
- Software Security – Graph algorithms for vulnerability detection

Questions?

zahmaad.github.io