Time & Space Complexity - Complete Topics & Explanations

A. Basic Concepts

Time Complexity: Kitna waqt lagta hai algorithm ko run karne mein, input size ke hisaab se.

Space Complexity: Kitni memory lagti hai algorithm ko run karte waqt.

Input Size (n): Yeh input data ka size hai, jisse performance measure ki jati hai.

Time vs Space: Time speed batata hai, Space memory batata hai.

B. Asymptotic Notations

Big O: Worst-case performance.

Big Omega: Best-case performance.

Big Theta: Average or exact performance.

Yeh notations estimate karte hain code kis speed se chalega.

C. Types of Time Complexities

O(1): Constant - Jaise ek element access karna.

O(log n): Logarithmic - Jaise binary search.

O(n): Linear - Jaise simple loop.

O(n log n): Linearithmic - Jaise merge sort.

O(n^2): Quadratic - Jaise nested loop.

O(2^n), O(n!): Exponential & factorial - Bohat slow algorithms.

D. Types of Space Complexities

O(1): Constant - Fixed variables.

O(n): Linear - Input ke proportional memory.

Recursive stack: Jab function recursion use karta hai.

Auxiliary space: Extra space jo function ne use ki.

E. Case Analysis

Best Case: Jab input ideal ho.

Worst Case: Jab input worst ho.

Average Case: Normal expected input.

Amortized: Average over multiple operations.

F. Time Complexity in Code

Loops: O(n), nested loops: O(n^2).

Conditionals: Affect nahi karti time complexity ko.

Function Calls: Agar recursion hai to stack bhi count hoti hai.

Master Theorem: Recursive algorithms analyse karne ke liye.

G. Space Complexity in Code

Variables: Constant space.

Arrays/Objects: Space increases with input.

Recursion stack: Har recursive call memory use karta hai.

Extra structures: Sets, maps extra space lete hain.

H. Common Algorithm Complexities

Linear Search: O(n)

Binary Search: O(log n)

Bubble Sort: O(n^2)

Merge Sort: O(n log n)

Hash Tables: Average O(1)

DFS/BFS: O(V + E) (graph traversal)

I. Comparison & Optimization

Time vs Memory ka tradeoff hota hai.

Kuch algorithms fast hain magar zyada memory lete hain.

Optimize karna hota hai: speed bhi achi ho aur memory bhi kam lage.