

Time Complexity of Algorithms



ARRAYS

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Accessing an element	$O(1)$	$O(1)$	$O(1)$
Updating an element	$O(1)$	$O(1)$	$O(1)$
Deleting an element	$O(n)$	$O(n)$	$O(1)$
Inserting an element	$O(n)$	$O(n)$	$O(1)$
Searching for an element	$O(n)$	$O(n)$	$O(1)$

Algorithm complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Quicksort	$O(n^2)$	$O(n \log(n))$	$O(n \log(n))$	$O(\log(n))$
Mergesort	$O(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$	$O(n)$
Heapsort	$O(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$	$O(1)$
Bubble Sort	$O(n^2)$	$O(n^2)$	$O(n)$	$O(1)$
Insertion Sort	$O(n^2)$	$O(n^2)$	$O(n)$	$O(1)$
Selection Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(1)$
Binary Search	$O(\log(n))$	$O(\log(n))$	$O(1)$	$O(1)$
Linear Search	$O(n)$	$O(n)$	$O(1)$	$O(1)$

STRINGS

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Accessing	$O(1)$	$O(1)$	$O(1)$
Deleting	$O(n)$	$O(n)$	$O(1)$
Inserting	$O(n)$	$O(n)$	$O(1)$
Searching (n = string length m = pattern length)	$O(n * m)$	$O(n)$	$O(1)$
Slicing (n = string length)	$O(n)$	$O(n)$	$O(n)$
Concatenating (n, m = string lengths)	$O(n + m)$	$O(n + m)$	$O(n)$
Comparison (n = shorter string length)	$O(n)$	$O(n)$	$O(n)$
Inserting (Trie) (m = key length)	$O(m)$	$O(m)$	$O(1)$
Searching (Trie) (m = key length)	$O(m)$	$O(m)$	$O(1)$

Algorithm complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Radix sort (m = longest string length)	$O(n * m)$	$O(n * m)$	$O(n * m)$	$O(n + m)$
Naive string search (m = size of pattern)	$O(m * (n - m + 1))$	$O(n * m)$	$O(n)$	$O(1)$
Knuth-Morris-Pratt search	$O(m + n)$	$O(n)$	$O(n)$	$O(m)$
Boyer-Moore string search	$O(n * m)$	$O(n)$	$O(n/m)$	$O(m)$
Rubin-Karp Algorithm	$O(m * (n - m + 1))$	$O(n + m)$	$O(m)$	$O(m)$

STACKS & QUEUES

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Delete (Stack)	$O(1)$	$O(1)$	$O(1)$
Insert (Stack)	$O(1)$	$O(1)$	$O(1)$
Search (Stack)	$O(n)$	$O(n)$	$O(1)$
Peek/Top (Stack)	$O(1)$	$O(1)$	$O(1)$
Delete (Queue)	$O(1)$	$O(1)$	$O(1)$
Insert (Queue)	$O(1)$	$O(1)$	$O(1)$
Search (Queue)	$O(n)$	$O(n)$	$O(1)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Linear Search	$O(n)$	$O(n)$	$O(1)$	$O(1)$

Stack: **LIFO** (Last In First Out)

Queue: **FIFO** (First In First Out)

LINKED LISTS

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Accessing	$O(n)$	$O(n)$	$O(1)$
Deleting (after search)	$O(1)$	$O(1)$	$O(1)$
Inserting (after search)	$O(1)$	$O(1)$	$O(1)$
Searching	$O(n)$	$O(n)$	$O(1)$
Traversing	$O(n)$	$O(n)$	$O(n)$
Access (Skip List)	$O(n)$	$O(\log n)$	$O(\log n)$
Delete (Skip List)	$O(n)$	$O(\log n)$	$O(\log n)$
Insert (Skip List)	$O(n)$	$O(\log n)$	$O(\log n)$
Search (Skip List)	$O(n)$	$O(\log n)$	$O(\log n)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Mergesort	$O(n \log n)$	$O(n \log n)$	$O(n \log n)$	$O(n)$
Bubble Sort	$O(n^2)$	$O(n^2)$	$O(n)$	$O(1)$
Selection Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(1)$
Insertion Sort	$O(n^2)$	$O(n^2)$	$O(n)$	$O(1)$
Linear Search	$O(n)$	$O(n)$	$O(1)$	$O(1)$

TREES

(SPACE-TIME COMPLEXITY)

Time complexity:

		Worst Case Scenario	Average Case Scenario	Best Case Scenario
Binary Search Tree, Cartesian Tree, KD Tree	Delete	$O(n)$	$O(\log n)$	$O(\log n)$
	Insert	$O(n)$	$O(\log n)$	$O(\log n)$
	Search	$O(n)$	$O(\log n)$	$O(\log n)$
B-Tree, Red-Black Tree, Splay Tree, AVL Tree	Delete	$O(\log n)$	$O(\log n)$	$O(\log n)$
	Insert	$O(\log n)$	$O(\log n)$	$O(\log n)$
	Search	$O(\log n)$	$O(\log n)$	$O(\log n)$
Traversal		$O(n)$	$O(n)$	$O(n)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Depth-First Search (In-order, pre-order, and post-order traversal)	$O(n)$	$O(n)$	$O(n)$	$O(n)$
Breadth-First Search (Level-order traversal)	$O(n)$	$O(n)$	$O(n)$	$O(n)$
Tree Sort	$O(n^2)$	$O(n \log n)$	$O(n \log n)$	$O(n)$
Splaysort	$O(n \log n)$	$O(n \log n)$	$O(n)$	$O(n)$
Cartesian Tree Sort	$O(n \log n)$	$O(n \log n)$	$O(n)$	$O(n)$

GRAPHS

(SPACE-TIME COMPLEXITY)

Time complexity:

		Worst Case Scenario	Average Case Scenario	Best Case Scenario
Insert Vertex	Adjacency List	$O(1)$	$O(1)$	$O(1)$
	Adjacency Matrix	$O(V^2)$	$O(V^2)$	$O(V^2)$
	Incidence Matrix	$O(V \cdot E)$	$O(V \cdot E)$	$O(V \cdot E)$
Remove Vertex	Adjacency List	$O(E)$	$O(E)$	$O(E)$
	Adjacency Matrix	$O(V^2)$	$O(V^2)$	$O(V^2)$
	Incidence Matrix	$O(V \cdot E)$	$O(V \cdot E)$	$O(V \cdot E)$
Insert Edge	Adjacency List	$O(1)$	$O(1)$	$O(1)$
	Adjacency Matrix	$O(1)$	$O(1)$	$O(1)$
	Incidence Matrix	$O(V \cdot E)$	$O(V \cdot E)$	$O(V \cdot E)$
Remove Edge	Adjacency List	$O(V)$	$O(V)$	$O(V)$
	Adjacency Matrix	$O(1)$	$O(1)$	$O(1)$
	Incidence Matrix	$O(V \cdot E)$	$O(V \cdot E)$	$O(V \cdot E)$
Check if Vertices Adjacent	Adjacency List	$O(V)$	$O(V)$	$O(V)$
	Adjacency Matrix	$O(1)$	$O(1)$	$O(1)$
	Incidence Matrix	$O(E)$	$O(E)$	$O(E)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Breadth-First Search	$O(V+E)$	$O(V+E)$	$O(V+E)$	$O(V)$
Depth-First Search	$O(V+E)$	$O(V+E)$	$O(V+E)$	$O(V)$
A* Search	$O(E)$	$O(E)$	$O(E)$	$O(V)$
Dijkstra's algorithm	$O(V^2)$	$O(E \cdot \log(V))$	$O(E \cdot \log(V))$	$O(V)$
Floyd-Warshall	$O(V^3)$	$O(V^3)$	$O(V^3)$	$O(V^2)$

MAPS

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Updating an element	$O(n)$	$O(1)$	$O(1)$
Inserting an element	$O(n)$	$O(1)$	$O(1)$
Deleting an element	$O(n)$	$O(1)$	$O(1)$
Searching for an element	$O(n)$	$O(1)$	$O(1)$
Insert (TreeMap)	$O(\log n)$	$O(\log n)$	$O(1)$
Delete (TreeMap)	$O(\log n)$	$O(\log n)$	$O(1)$
Search (TreeMap)	$O(\log n)$	$O(\log n)$	$O(1)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Bucket Sort (k = buckets)	$O(n^2)$	$O(n + k)$	$O(n + k)$	$O(n)$
Insertion Sort	$O(n^2)$	$O(n^2)$	$O(n)$	$O(1)$
Selection Sort	$O(n^2)$	$O(n^2)$	$O(n^2)$	$O(1)$
Heapsort	$O(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$	$O(1)$
Hash-based Search	$O(n)$	$O(1)$	$O(1)$	$O(1)$
Binary Search	$O(\log(n))$	$O(\log(n))$	$O(1)$	$O(1)$
Linear Search	$O(n)$	$O(n)$	$O(1)$	$O(1)$
Rabin-Karp Algorithm	$O(m*(n-m+1))$	$O(n + m)$	$O(m)$	$O(m)$

HEAPS

(SPACE-TIME COMPLEXITY)

Time complexity:

	Worst Case Scenario	Average Case Scenario	Best Case Scenario
Insert	$O(\log n)$	$O(\log n)$	$O(1)$
Delete	$O(\log n)$	$O(\log n)$	$O(1)$
Find min/max	$O(1)$	$O(1)$	$O(1)$
Search	$O(n)$	$O(n)$	$O(1)$
Insert (Fibonacci/Binomial)	$O(\log n)$	$O(1)$	$O(1)$
Increase/Decrease key	$O(\log n)$	$O(\log n)$	$O(1)$
Extract min/max	$O(\log n)$	$O(\log n)$	$O(\log n)$

Algorithm Complexity:

	Time Complexity			Space Complexity
	Worst Case	Average Case	Best Case	
Heapsort	$O(n \log(n))$	$O(n \log(n))$	$O(n \log(n))$	$O(1)$
Smoothsort	$O(n \log(n))$	$O(n \log(n))$	$O(n)$	$O(n)$
Quick select	$O(n^2)$	$O(n)$	$O(n)$	$O(1)$
Linear Search	$O(n)$	$O(n)$	$O(1)$	$O(1)$
Dijkstra's shortest path	$O(V^2)$	$O(E * \log(V))$	$O(E * \log(V))$	$O(V)$