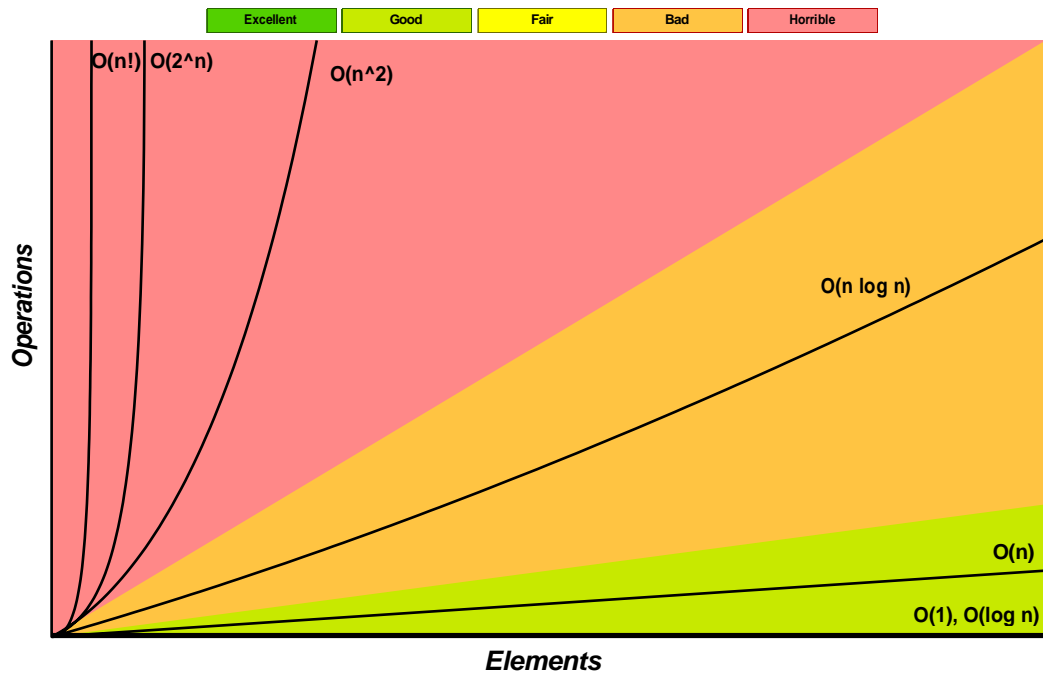


## Big-O Complexity Chart



## Common Data Structure Operations

| Data Structure     | Time Complexity |             |             |             |             |             |             |             | Space Complexity |
|--------------------|-----------------|-------------|-------------|-------------|-------------|-------------|-------------|-------------|------------------|
|                    | Average         |             |             |             | Worst       |             |             |             | Worst            |
|                    | Access          | Search      | Insertion   | Deletion    | Access      | Search      | Insertion   | Deletion    |                  |
| Array              | $O(1)$          | $O(n)$      | $O(n)$      | $O(n)$      | $O(1)$      | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$           |
| Stack              | $O(n)$          | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$      | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$           |
| Queue              | $O(n)$          | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$      | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$           |
| Singly-Linked List | $O(n)$          | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$      | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$           |
| Doubly-Linked List | $O(n)$          | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$      | $O(n)$      | $O(1)$      | $O(1)$      | $O(n)$           |
| Skip List          | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$      | $O(n \log n)$    |
| Hash Table         | N/A             | $O(1)$      | $O(1)$      | $O(1)$      | N/A         | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$           |
| Binary Search Tree | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$           |
| Cartesian Tree     | N/A             | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | N/A         | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$           |
| B-Tree             | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$           |
| Red-Black Tree     | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$           |
| Splay Tree         | N/A             | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | N/A         | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$           |
| AVL Tree           | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$           |
| KD Tree            | $O(\log n)$     | $O(\log n)$ | $O(\log n)$ | $O(\log n)$ | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$      | $O(n)$           |

## Array Sorting Algorithms

| Algorithm      | Time Complexity |                   |                   | Space Complexity |
|----------------|-----------------|-------------------|-------------------|------------------|
|                | Best            | Average           | Worst             | Worst            |
| Quicksort      | $O(n \log(n))$  | $O(n \log(n))$    | $O(n^2)$          | $O(\log(n))$     |
| Mergesort      | $O(n \log(n))$  | $O(n \log(n))$    | $O(n \log(n))$    | $O(n)$           |
| Timsort        | $O(n)$          | $O(n \log(n))$    | $O(n \log(n))$    | $O(n)$           |
| Heapsort       | $O(n \log(n))$  | $O(n \log(n))$    | $O(n \log(n))$    | $O(1)$           |
| Bubble Sort    | $O(n)$          | $O(n^2)$          | $O(n^2)$          | $O(1)$           |
| Insertion Sort | $O(n)$          | $O(n^2)$          | $O(n^2)$          | $O(1)$           |
| Selection Sort | $O(n^2)$        | $O(n^2)$          | $O(n^2)$          | $O(1)$           |
| Tree Sort      | $O(n \log(n))$  | $O(n \log(n))$    | $O(n^2)$          | $O(n)$           |
| Shell Sort     | $O(n \log(n))$  | $O(n(\log(n))^2)$ | $O(n(\log(n))^2)$ | $O(1)$           |
| Bucket Sort    | $O(n+k)$        | $O(n+k)$          | $O(n^2)$          | $O(n)$           |
| Radix Sort     | $O(nk)$         | $O(nk)$           | $O(nk)$           | $O(n+k)$         |
| Counting Sort  | $O(n+k)$        | $O(n+k)$          | $O(n+k)$          | $O(k)$           |
| Cubesort       | $O(n)$          | $O(n \log(n))$    | $O(n \log(n))$    | $O(n)$           |

## Graph Data Structure Operations

| Data Structure   | Time Complexity    |                    |                    |                    |                    |          |
|------------------|--------------------|--------------------|--------------------|--------------------|--------------------|----------|
|                  | Storage            | Add Vertex         | Add Edge           | Remove Vertex      | Remove Edge        | Query    |
| Adjacency list   | $O( V + E )$       | $O(1)$             | $O(1)$             | $O( V  +  E )$     | $O( E )$           | $O( V )$ |
| Incidence list   | $O( V + E )$       | $O(1)$             | $O(1)$             | $O( E )$           | $O( E )$           | $O( E )$ |
| Adjacency matrix | $O( V ^2)$         | $O( V ^2)$         | $O(1)$             | $O( V ^2)$         | $O(1)$             | $O(1)$   |
| Incidence matrix | $O( V  \cdot  E )$ | $O( V  \cdot  E )$ | $O( V  \cdot  E )$ | $O( V  \cdot  E )$ | $O( V  \cdot  E )$ | $O( E )$ |

## Graph Algorithms

| Algorithm                | Time Complexity    |                    | Space Complexity |
|--------------------------|--------------------|--------------------|------------------|
|                          | Average            | Worst              | Worst            |
| Dijkstra's algorithm     | $O( E  \log  V )$  | $O( V ^2)$         | $O( V  +  E )$   |
| A* search algorithm      | $O( E )$           | $O(b^d)$           | $O(b^d)$         |
| Prim's algorithm         | $O( E  \log  V )$  | $O( V ^2)$         | $O( V  +  E )$   |
| Bellman–Ford algorithm   | $O( E  \cdot  V )$ | $O( E  \cdot  V )$ | $O( V )$         |
| Floyd-Warshall algorithm | $O( V ^3)$         | $O( V ^3)$         | $O( V ^2)$       |
| Topological sort         | $O( V  +  E )$     | $O( V  +  E )$     | $O( V  +  E )$   |