What are Data Structures ??

↳ It is a way to organize and store data in memory.

Types of Data Structure

Linear DS	Hierarchy	Network
Arrays	Binary Tree	Graphs
Linked list	Binary Search Tree	
Stacks	Ternary Tree	
Queue	n-ary tree	
Deque	Heaps	
DLL	Tries	
⋮	suffix trees	
	⋮	

- → Learn about how the DS looks in memory
- → How data can be added / removed / updates in the DS along with Time Complexity
- → To code the whole DS on your own.
- → Problem solving

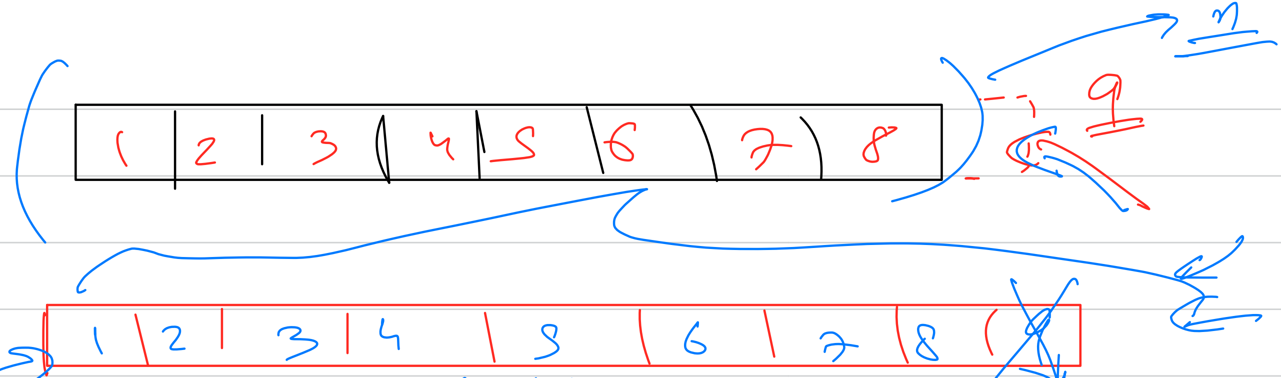
Designing your own Vector / Arraylist / list

Vector

→ This is a linear data structure
→ This posses almost all the properties of arrays.

Q. How vectors are different from arrays →

→ A normal array cannot directly grow or shrink at runtime.
But vector can.



O(n)

addition

add at last

O(n) → delete

add at first

add at i'th pos'

	add at first	add at last	add at i
arrays	$O(n)$	$O(n)$	$O(n)$
Vectors	$O(n)$	$O(1)$	$O(n)$

Qs How vectors manage to get $O(1)$ for add at last when they are almost similar to arrays ??

→ Vectors internally use arrays to store data. but in a smart way

→ So whenever vectors become full while adding new data, they double the size of the internal array copy all elements & then add new element.

$\rightarrow 1, 2, 3, 4, 5, 6, 7, 8, 9 \rightarrow$

| 1 | → 1

| 1 | 2 | → $2 \rightarrow (1+1)$

| 1 | 2 | 3 | | → $3 \rightarrow (1+2)$

| 1 | 2 | 3 | 4 | → 1

| 1 | 2 | 3 | 4 | 5 | | | | → $5 \rightarrow (1+4)$

6 → 1

7 → 1

8 → 1

$9 \rightarrow (1+8)$

⋮

n elements added

$$\text{Avg time} \rightarrow \frac{\text{Total sum of operation}}{\text{Total elements}}$$

$$= \frac{(1+2+3+1+5+1+1+1+1+9 \ldots\ldots)}{n}$$

$$\Downarrow$$

$$= \frac{(1+(1+1)+(1+2)+1+(1+4)+1+1+1+1+(1+8)\ldots)}{n}$$

$$\Rightarrow \frac{(1+1+1+1\ldots\ldots) + (1+2+4+8\ldots\ldots)}{n}$$

$$\Rightarrow \frac{n + (1+2^1+2^2+2^3 \ldots\ldots)}{n}$$

$$\Rightarrow \left(n + \frac{1 \times (2^{\log_2 n} - 1)}{2-1} \right) / n$$

$$n \geq 1 + 2^k$$

$$n \geq 2^k$$

$$\log_2 n \geq \log 2^k$$

$$k \leq \log_2 n$$

$n \approx 10^5$

$2^n \approx n$

$$\left(\frac{a \times r^{n}-1}{r-1}\right)$$

$$= \frac{n + \left(\frac{1 \times 2^{\log_2 n} - 1}{2-1}\right)}{n}$$

$$2^{\log_2 n} \Rightarrow n$$

$$= \frac{n + n - 1}{n}$$

$$\Rightarrow \frac{2n-1}{n} \Rightarrow \text{const}$$

$$\Theta(1)$$ ✓

$$mid = \frac{l+h}{2}$$

by magnitude

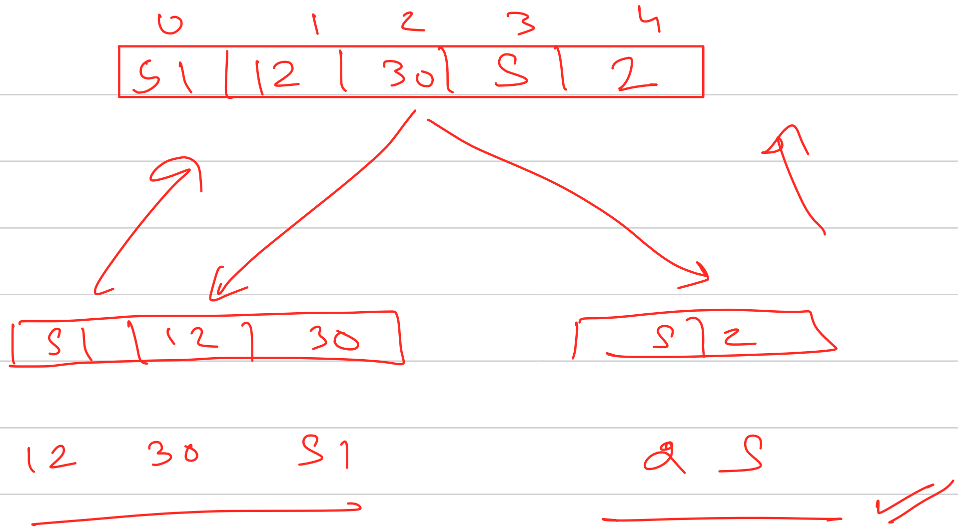
$$mid = l + \left(\frac{h-l}{2}\right)$$

$$mid = \left(\frac{l+h}{2}\right)$$

add & sub 'l' from num

$$\Rightarrow \frac{l+h+l-l}{2} \Rightarrow \frac{2l+h-l}{2}$$

$$\Rightarrow \frac{2l}{2} + \frac{h-l}{2} \Rightarrow l + \frac{h-l}{2}$$


0 1 2 3 4
51 12 30 5 2
51 12 30
5 2
12 30 51
2 5

Binary Search

1 half

2nd half

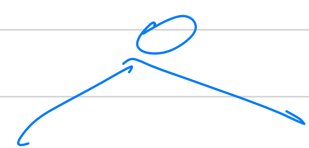
lo

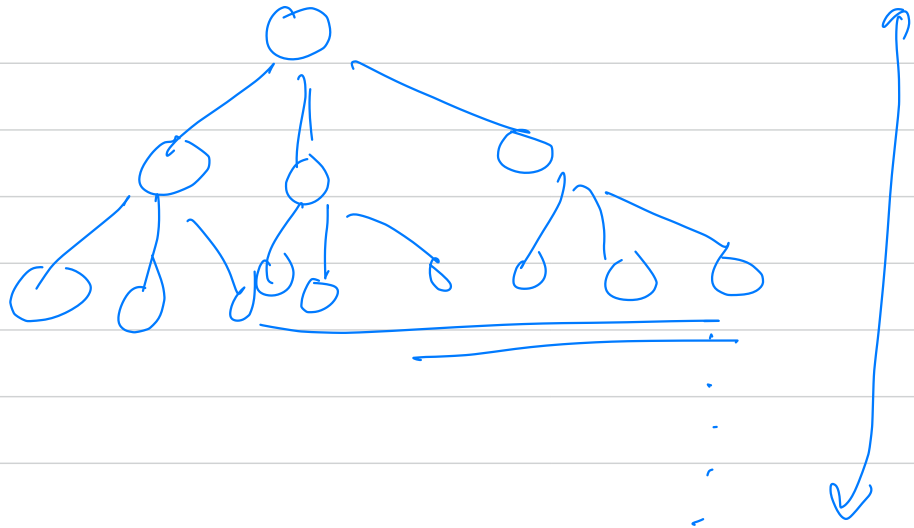
hi

1/2 ✓

1/2 ✗

Binary Search tree



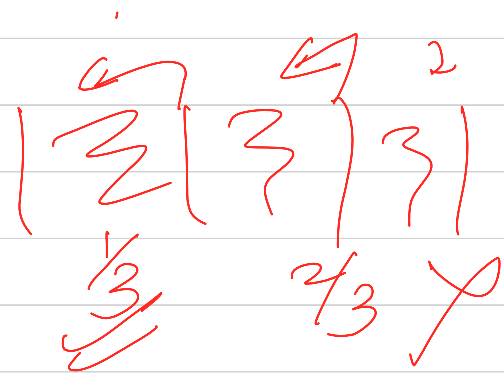


Binary Search vs Ternary Search

Divide your search space into 2 halves

Divide your search space into 3 halves

→ $O(\log_2 n)$



if (mid == ele)

else {

}

B.S

$$n \rightarrow \frac{n}{2} \rightarrow \frac{n}{4} \rightarrow \frac{n}{8} \cdots\cdots \frac{1}{2^k}$$

$$\frac{n}{2^k} = 1$$

$$k = \log_2 n$$

$$T(n) = T(n/2) + O(1)$$

$$T(n/2) = T(n/4) + O(1)$$

$$T(n/4) = T(n/8) + O(1)$$

$$\vdots$$

$$T(2) = T(1) + O(1)$$

$$T(n) = T(1) + \log_2 n \times 1$$

$$\underset{\text{steps}}{k} = \log_2 n$$

$$\Rightarrow T(n) = T(1) + k\,O(1)$$

$$= T(n) = c\log_2 n$$

$$T(n) = O(\log_2 n)$$

if (mid)

elif (m...)

else

$$T(n) = T(\cancel{n/3}) + O(2)$$
$$T(\cancel{n/3}) = T(\cancel{n/9}) + O(2)$$
$$T(\cancel{n/9}) = T(\cancel{n/27}) + O(2)$$
$$\vdots \qquad \vdots \qquad \vdots$$
$$T(\cancel{3}) = T(1) + O(2)$$

$\log_3 n$

$$T(n) = T(1) + \underline{\log_3 n \times 2}$$

$$n \to n/3 \to n/9 \to n/27 \ldots\ldots \frac{n}{3^k}$$

$$\underline{k = \log_3 n} \qquad \underline{T(n) = O(\log_3 n)}$$

$\log_{3} 81 \Rightarrow 4$

$\log_{2} 64 \rightarrow 6$

$\log_{3} 3^{n}$

Total comparisons in BS $\rightarrow \log_2 n$

Total Compars in TS $\rightarrow 2\log_3 n$

$2\log_3 n \Rightarrow 2 \times \frac{\log_2 n}{\log_2 3} \rightarrow$ const

$\frac{2}{\log_2 3} \log_2 n > 1 \times \log_2 n$

n significant longer