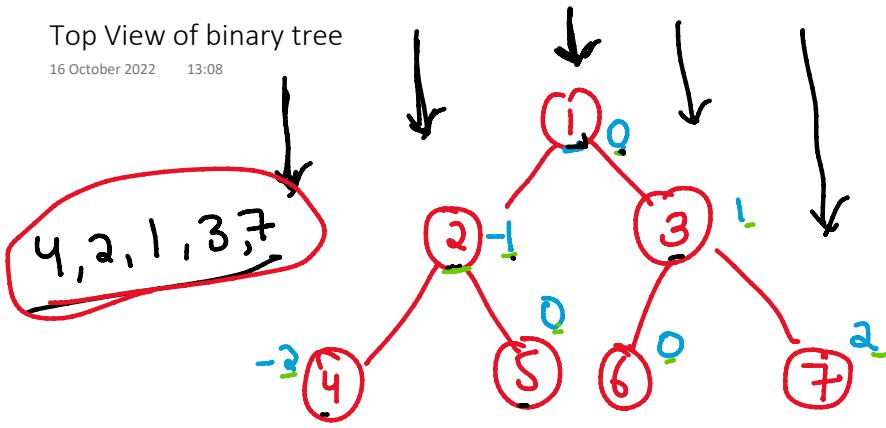


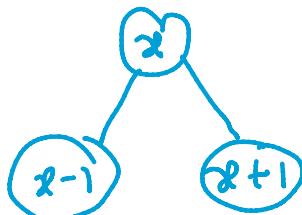
Top View of binary tree

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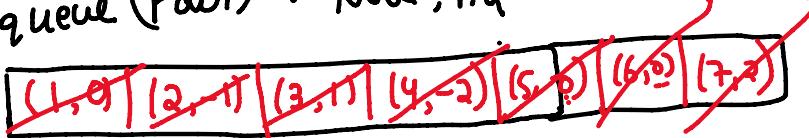


L to R

horizontal distance



queue (Pair) \rightarrow Node, hd



node = 1

hd = 0

left
push(left, hd -1)
right
push(right, hd +1)

-2
-1
0
1
2

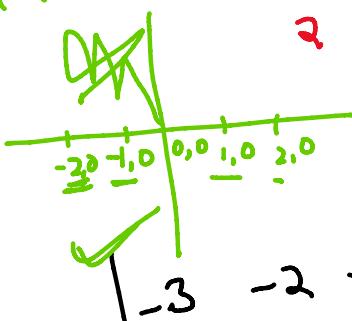


hashmap

hd	val
0	1
-1	2
1	3
-2	4
2	7

level order!

2 things
1. insertion
2. search



fall

3 4 5

$O(N)$



L to R

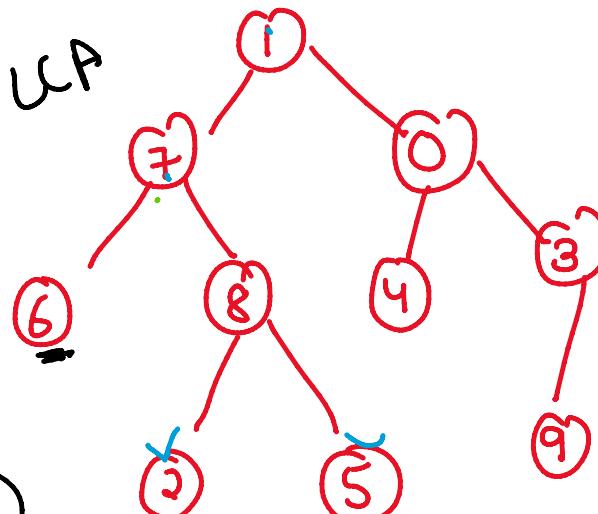
$O(1)$ \rightarrow unordered-map

$O(\log N)$ \rightarrow order-map

-2
-1
0
1
2

LCA

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$$8 = 8, 7, 1$$

$$9 = 9, 3, 0, 1$$

$$1 = 1$$

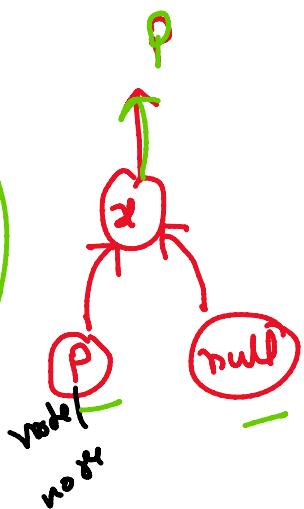
$$7 = 7, 1$$

$$\begin{aligned} \text{node1} &= 2 \\ \text{node2} &= 8 \end{aligned} \quad \Rightarrow \quad 8$$

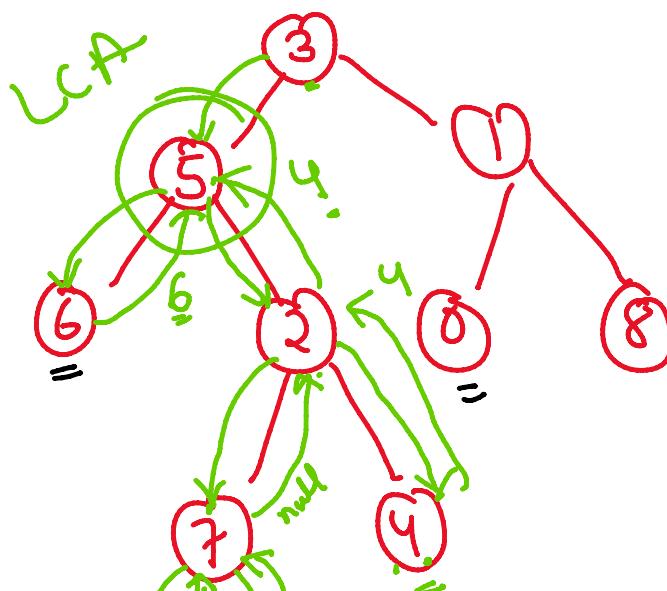
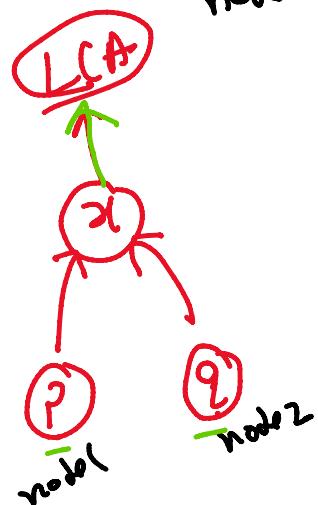
$\text{node1} = 2 \quad \text{node2} = 8$

$\text{node1} = 6 \quad \text{node2} = 7$

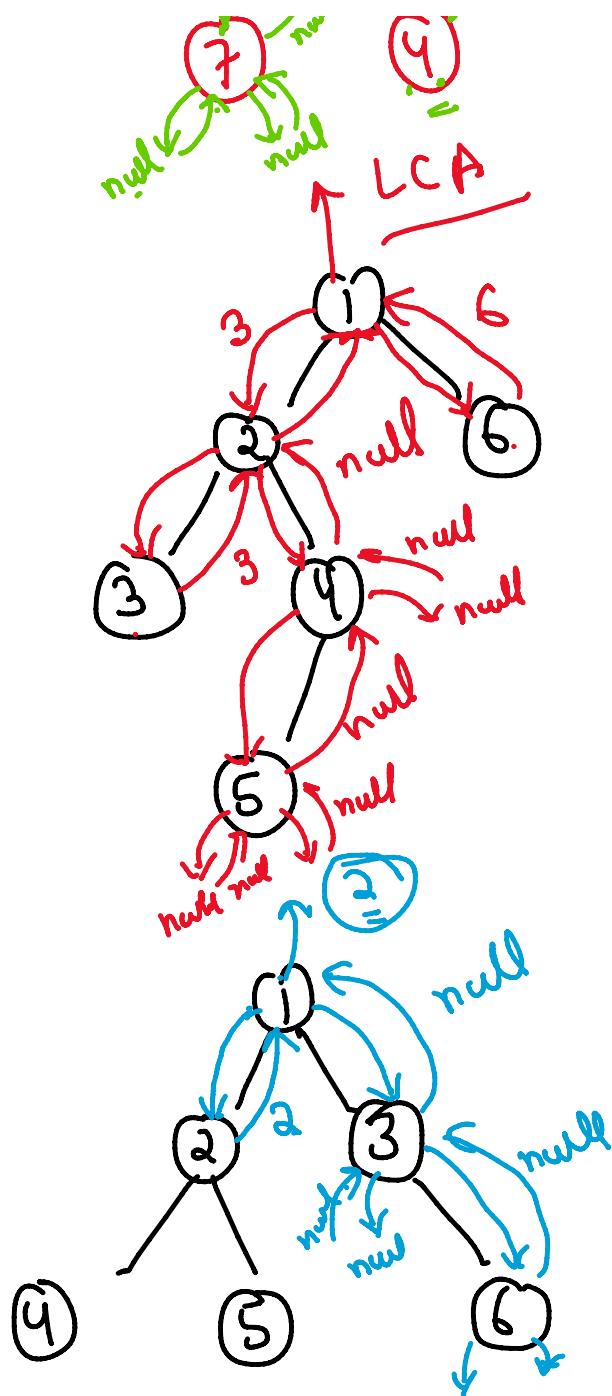
$\text{node1} = x \quad \text{node2} = null$



$$\begin{aligned} \text{node1} &= 7 \\ \text{node2} &= 4 \end{aligned} \quad \Rightarrow \quad 1$$



$$\begin{aligned} \text{node1} &= 6 \\ \text{node2} &= 4 \end{aligned} \quad \Rightarrow \quad 5$$

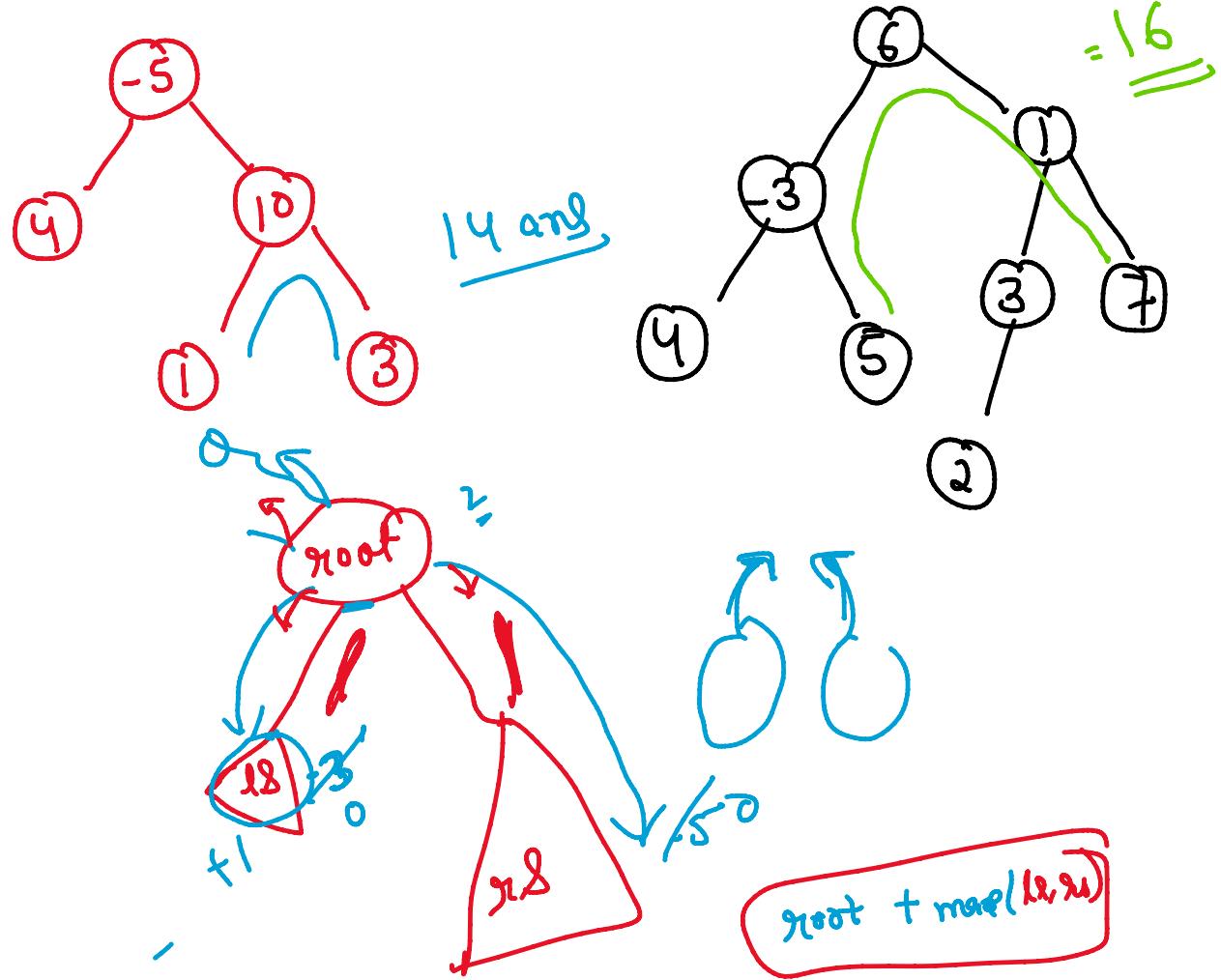


$\text{node1} = 3 \quad \boxed{1}$
 $\text{node2} = 6 \quad \boxed{2}$

$\text{node1} = 5 \quad \boxed{3}$
 $\text{node2} = 2 \quad \boxed{2}$

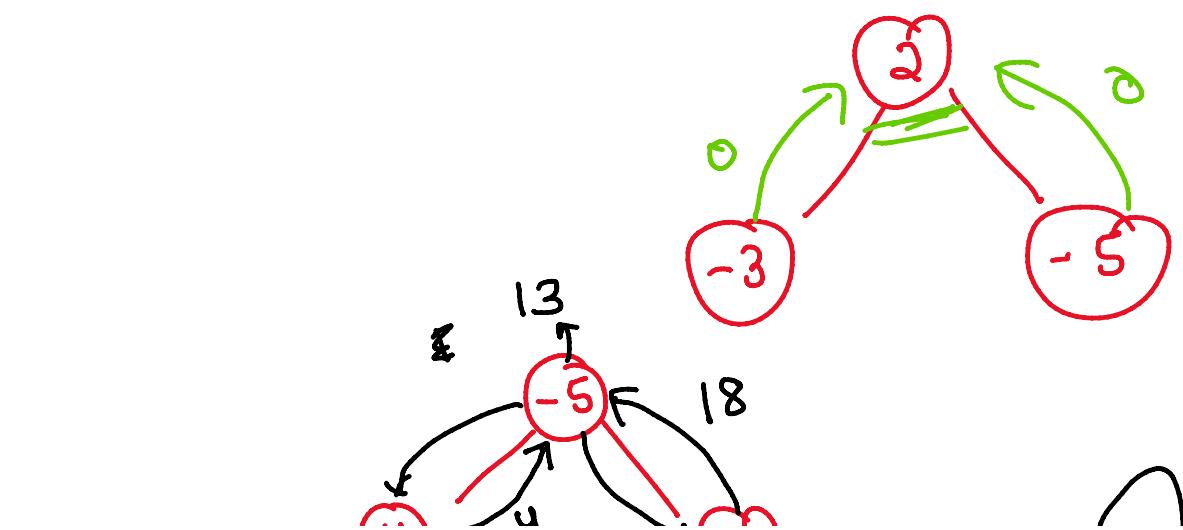
Maximum path sum in binary tree

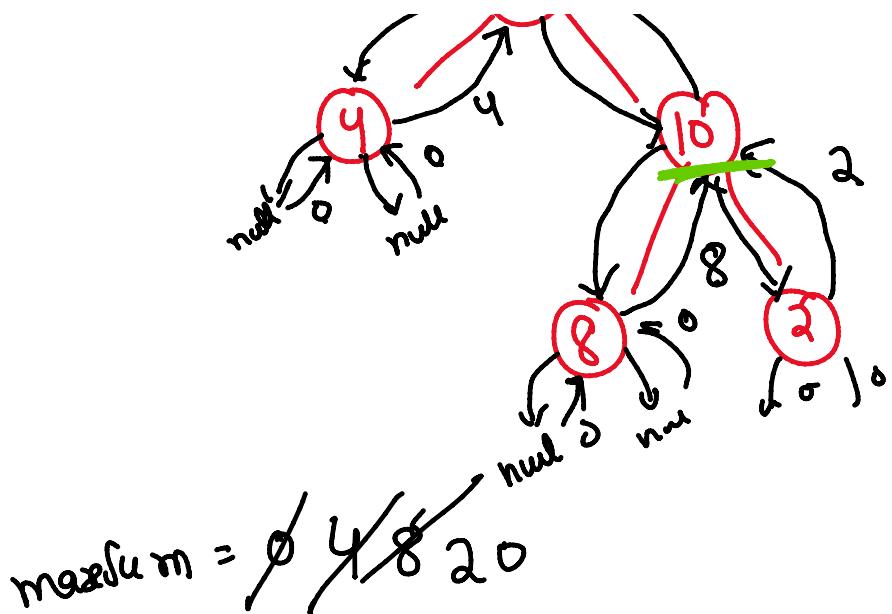
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$$\text{height} = \max(\text{lh}, \text{rh}) + 1$$

$$[\text{totalsum} = \text{lh} + \text{rh} + \text{root} \rightarrow \text{val}]$$





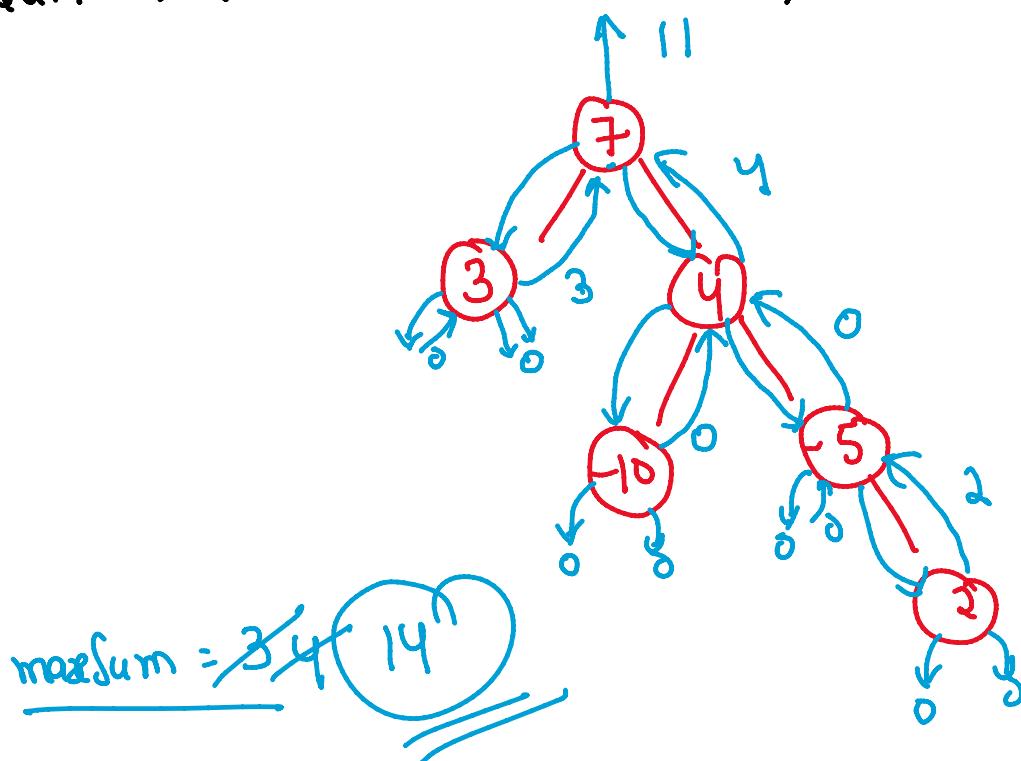
20

postorder

left
right
root

$$\text{sum} = \text{left} + \text{right} + \text{root.val}$$

$$\text{root.val} + \underline{\text{max(left, right)}}$$



⇒ 14

$$-5 + \max(0, 2)$$

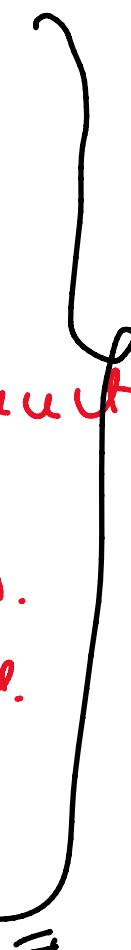
$$-5 + 2 = -3$$

$$-10 + \max(0, 0)$$

$$-10 + 0 = -10$$

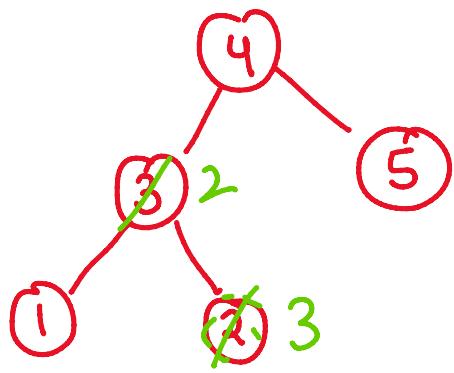
Practice questions

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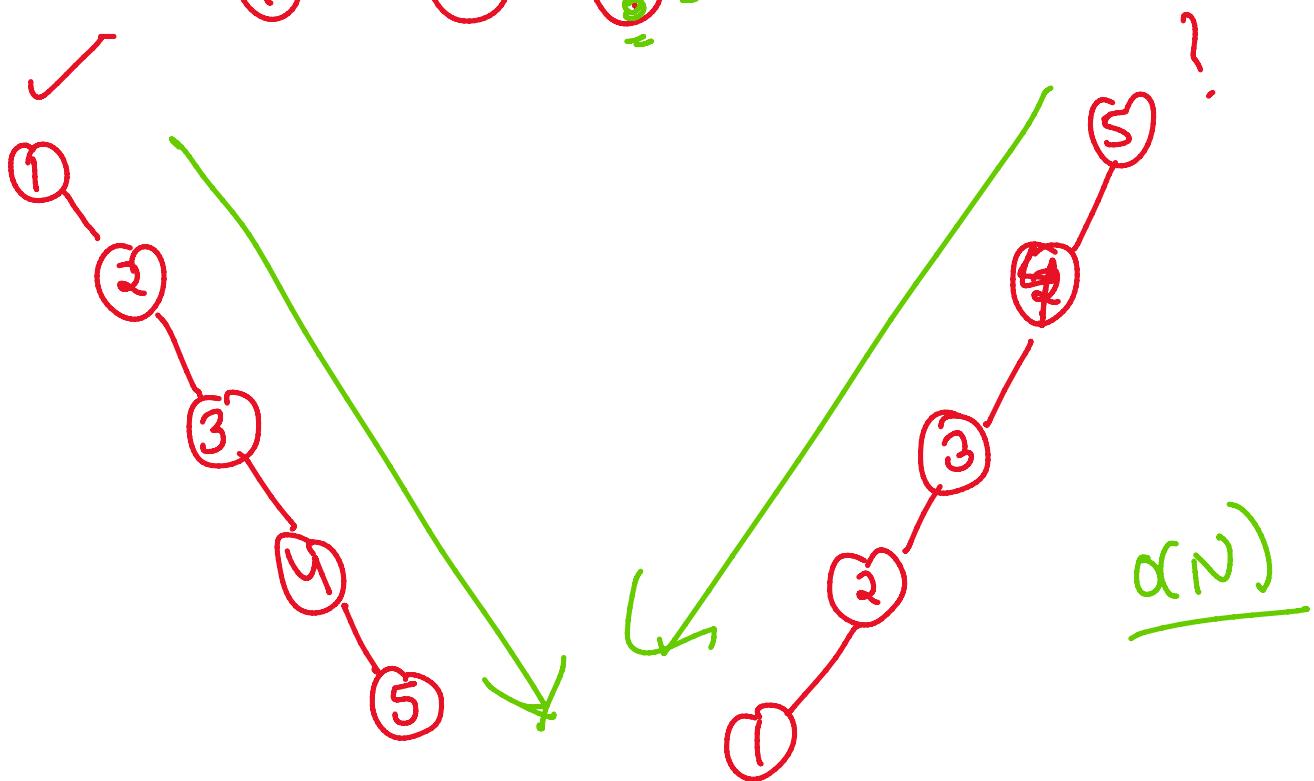
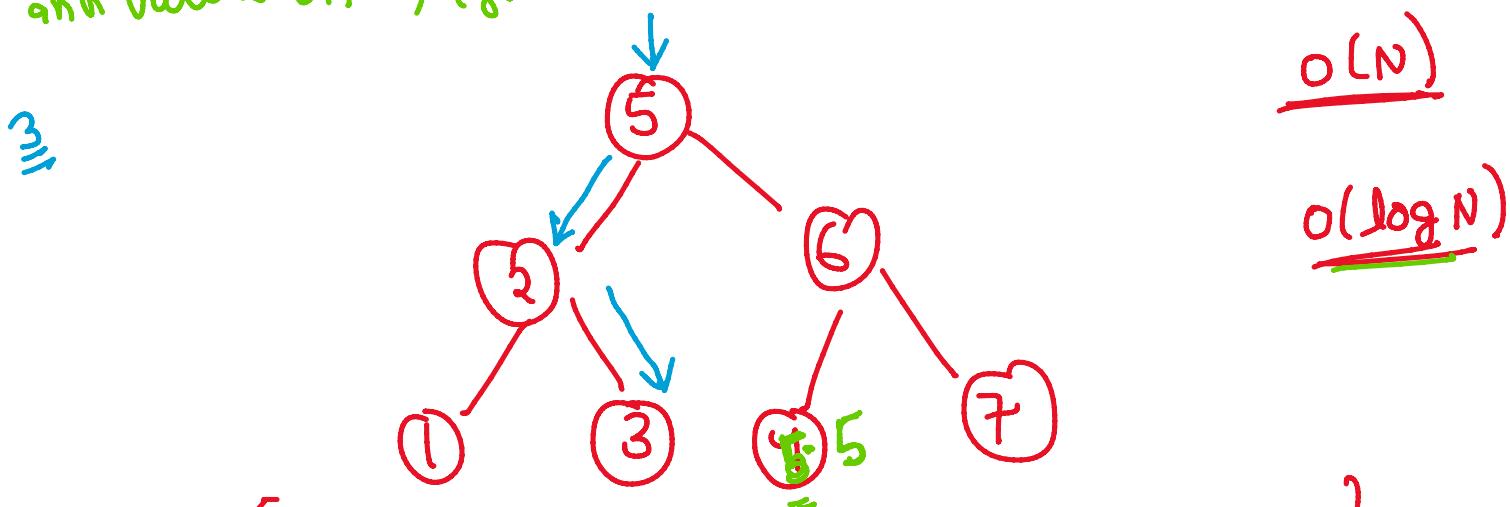
1. invert binary tree
 2. Transform to sum tree
 3. vertical order print
 4. All 4 views.
 5. Using Preorder and Inorder. construct tree.
 6. Diameter of tree
 7. Populating next right pointers.
 8. Serialize and Deserialize binary tree.
 9. Boundary traversal of tree.
 10. All nodes at distance K.
- 

Binary search trees (BST)

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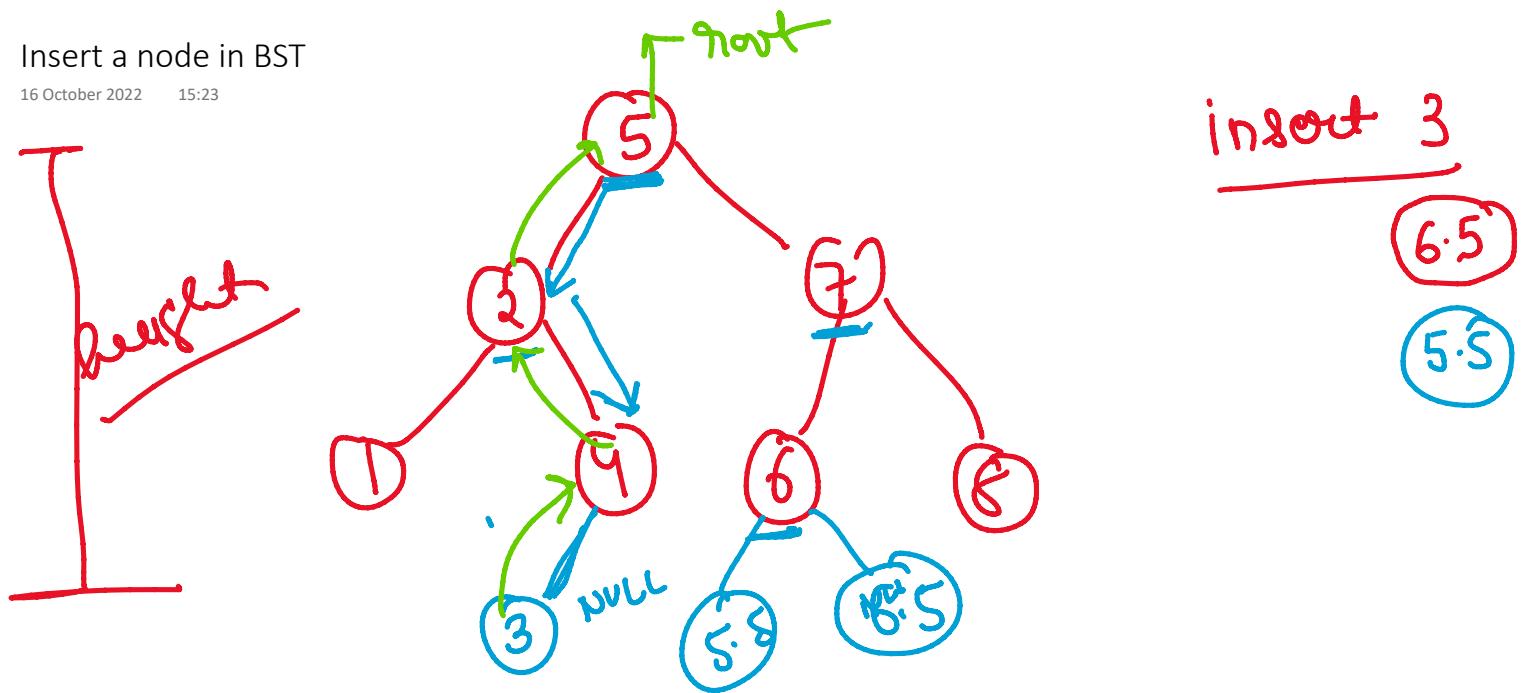
values on left should be smaller }
and values on right be greater }
each subtree should
be BST



○ * ○

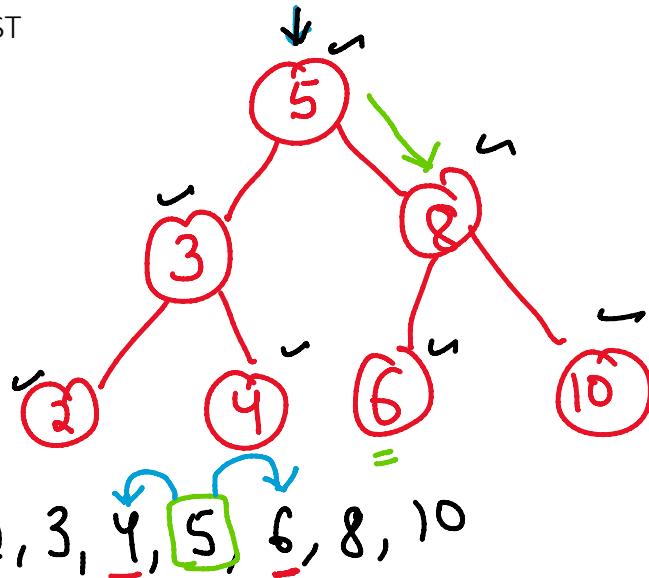
Insert a node in BST

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Delete a node in BST

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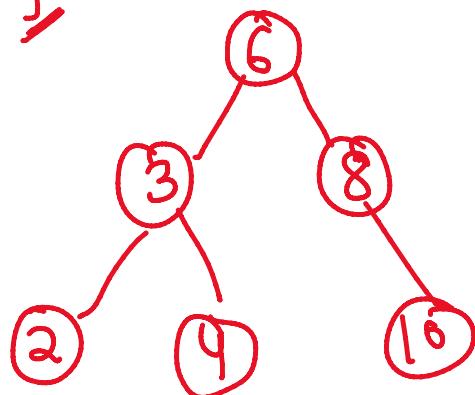


leaf = !
1 child = 9
2 child = 5

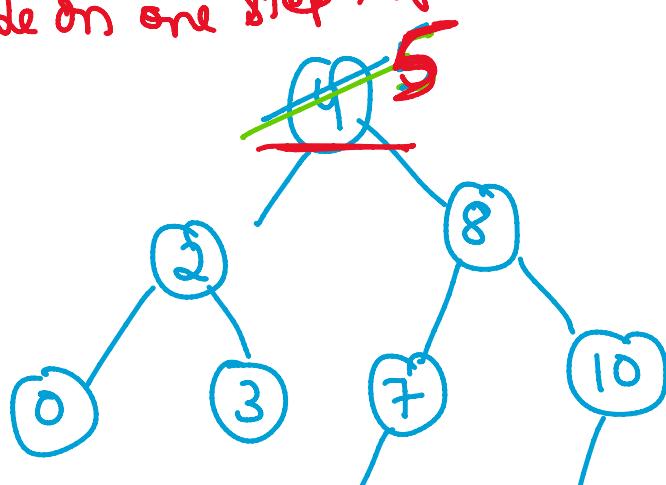
4 } correct
6 }

Inorder
left, root, right

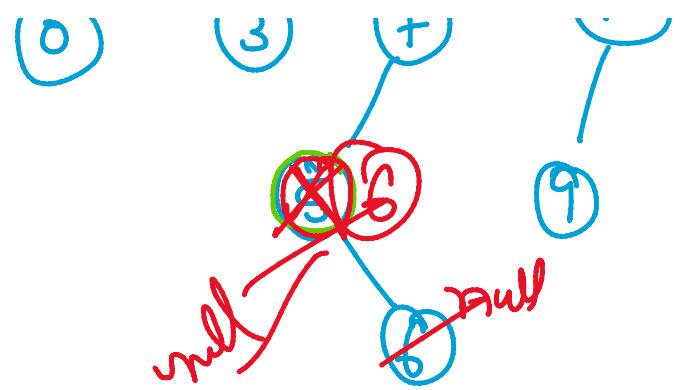
leaf node = 1 → return null
1 child = 2
2 child = 3, 8, 5



smallest node on subtree?
leftmost node on one step right.



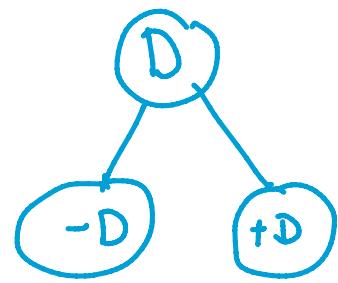
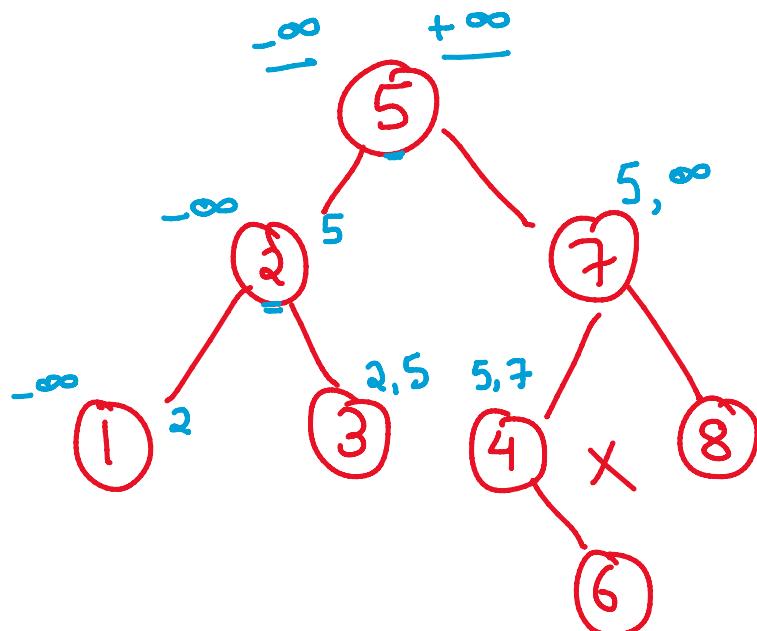
w. local node



1. leaf node
2. right child

Validate BST

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inorder
== true

