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450. Delete node in a BST

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Given a root node reference of a BST and a key, delete the node with the given key in the BST. Return the root node reference (possibly updated) of the BST.

Basically, the deletion can be divided into two stages:

1. Search for a node to remove.
2. If the node is found, delete the node.

Note: Time complexity should be O(height of tree).

Example:

```
root = [5,3,6,2,4,null,7]
key = 3

    5
   / \
  3   6
 / \   \
2   4   7

Given key to delete is 3. So we find the node with value 3 and delete it.

One valid answer is [5,4,6,2,null,null,7], shown in the following BST.

    5
   / \
  4   6
 /     \
2       7

Another valid answer is [5,2,6,null,4,null,7].

    5
   / \
  2   6
   \   \
    4   7
```

Solution

Three facts to know about BST

Here is list of facts which are better to know before the interview.

> Inorder traversal of BST is an array sorted in the ascending order.

To compute inorder traversal follow the direction `Left -> Node -> Right`.

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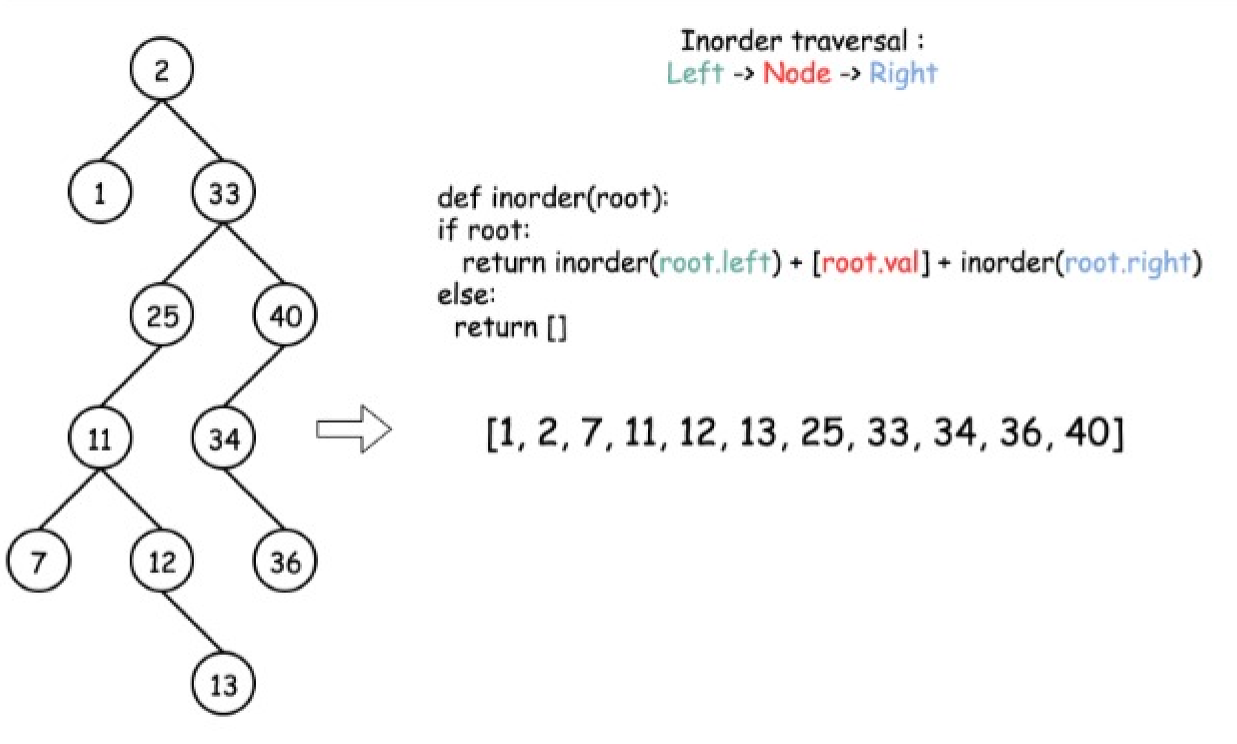
```python
def inorder(root):
    return inorder(root.left) + [root.val] + inorder(root.right) if root else []
```



> Successor = "after node", i.e. the next node, or the smallest node *after* the current one.

It's also the *next* node in the inorder traversal. To find a successor, go to the right once and then as many times to the left as you could.

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```python
def successor(root):
    root = root.right
    while root.left:
        root = root.left
    return root
```

> Predecessor = "before node", i.e. the previous node, or the largest node *before* the current one.

It's also the *previous* node in the inorder traversal. To find a predecessor, go to the left once and then as many times to the right as you could.

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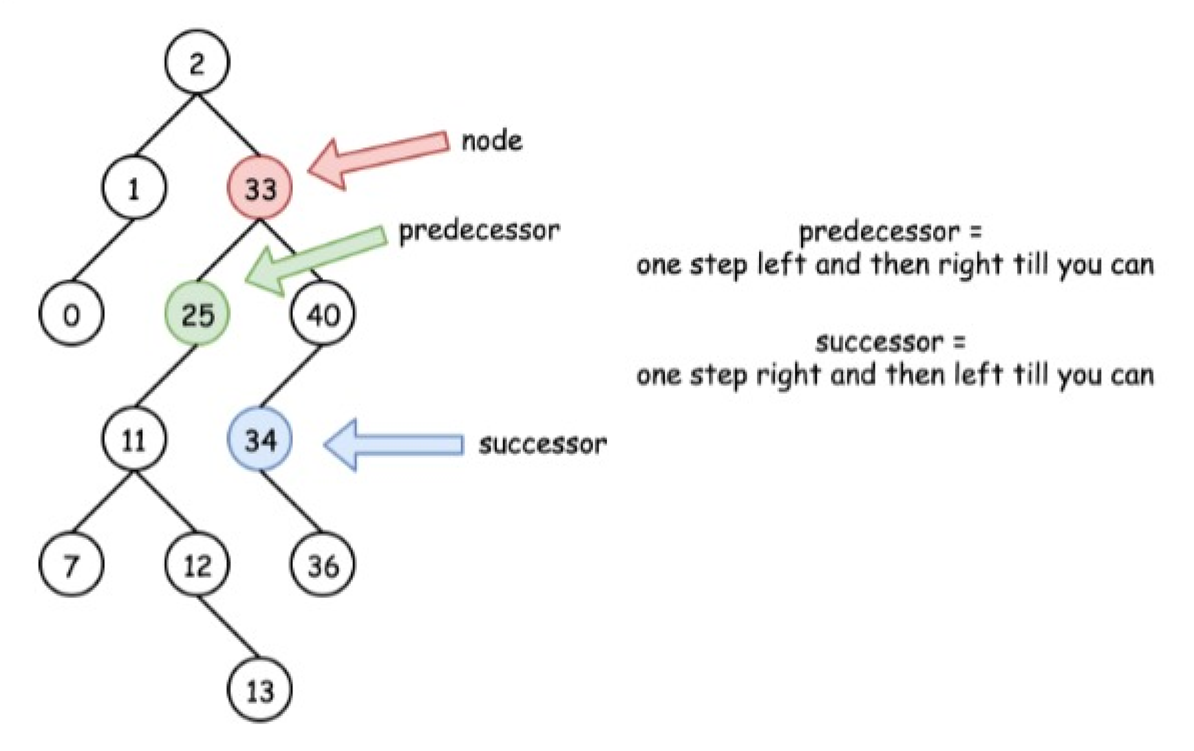
```python
def predecessor(root):
    root = root.left
    while root.right:
        root = root.right
    return root
```

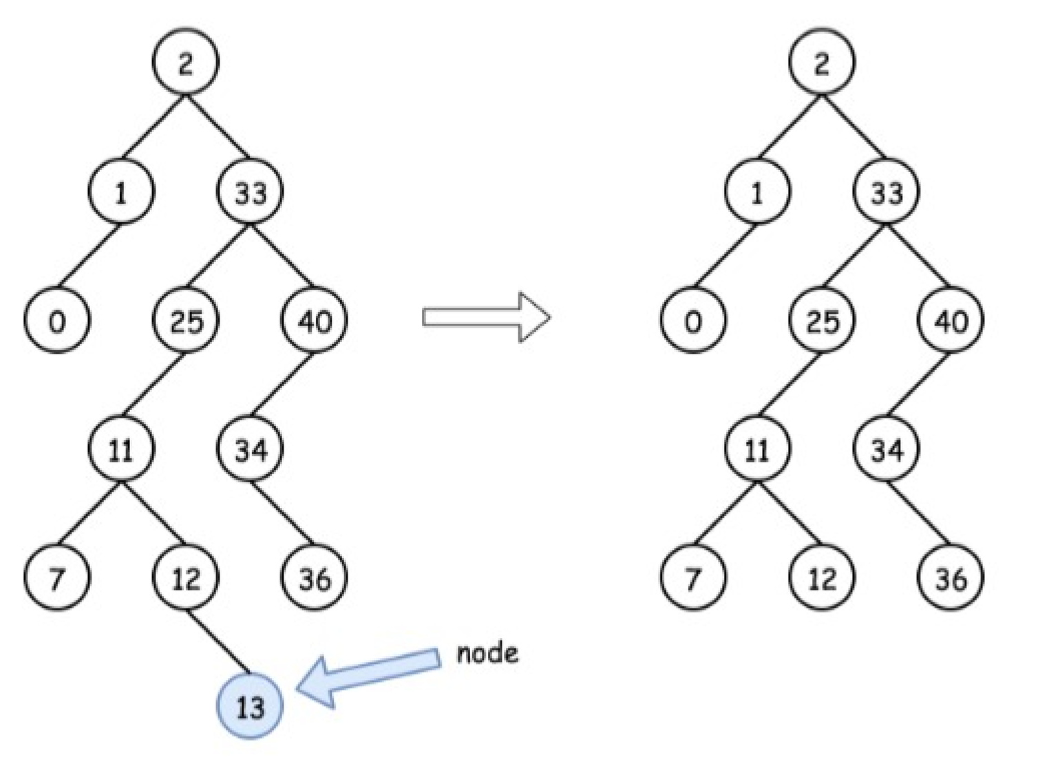


Approach 1: Recursion

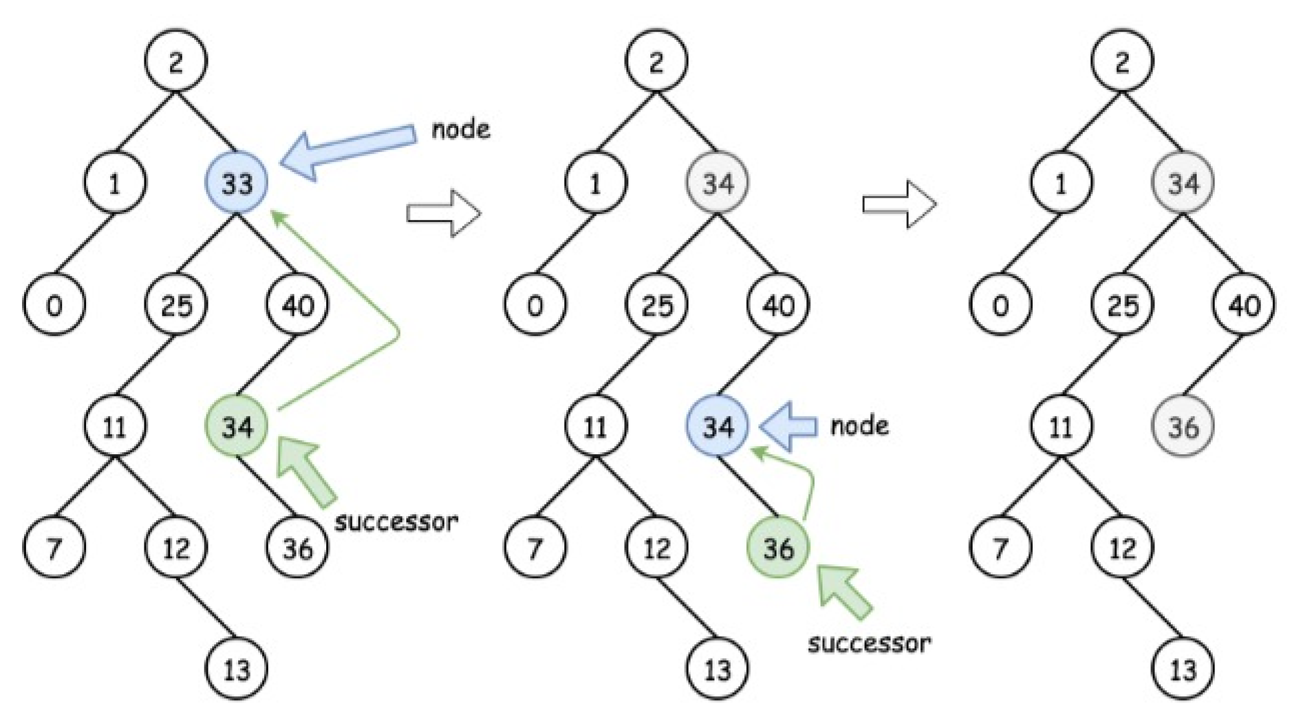
Intuition

There are three possible situations here :

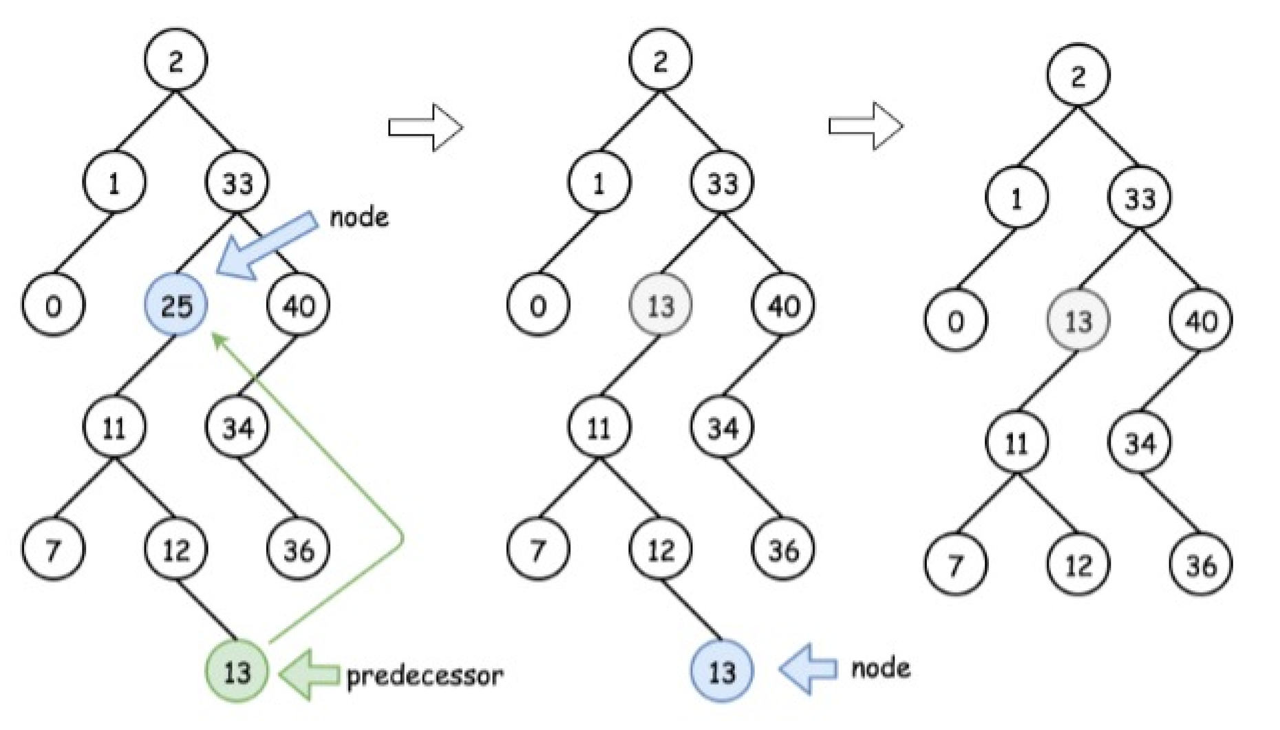
- Node is a leaf, and one could delete it straightforward : `node = null`.



- Node is not a leaf and has a right child. Then the node could be replaced by its *successor* which is somewhere lower in the right subtree. Then one could proceed down recursively to delete the successor.



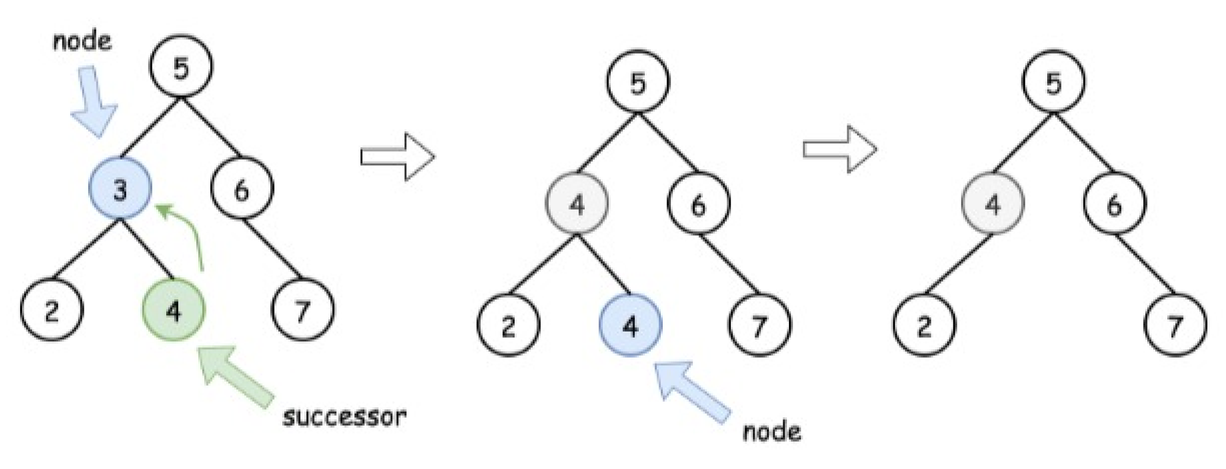
- Node is not a leaf, has no right child and has a left child. That means that its *successor* is somewhere upper in the tree but we don't want to go back. Let's use the *predecessor* here which is somewhere lower in the left subtree. The node could be replaced by its *predecessor* and then one could proceed down recursively to delete the predecessor.



Algorithm

- If `key > root.val` then delete the node to delete is in the right subtree `root.right = deleteNode(root.right, key)`.
- If `key < root.val` then delete the node to delete is in the left subtree `root.left = deleteNode(root.left, key)`.
- If `key == root.val` then the node to delete is right here. Let's do it :
  - If the node is a leaf, the delete process is straightforward : `root = null`.
  - If the node is not a leaf and has the right child, then replace the node value by a successor value `root.val = successor.val`, and then recursively delete the successor in the right subtree `root.right = deleteNode(root.right, root.val)`.
  - If the node is not a leaf and has only the left child, then replace the node value by a predecessor value `root.val = predecessor.val`, and then recursively delete the predecessor in the left subtree `root.left = deleteNode(root.left, root.val)`.
- Return `root`.

Implementation



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```python
class Solution:
    def successor(self, root):
        """
        One step right and then always left
        """
        root = root.right
        while root.left:
            root = root.left
        return root.val

    def predecessor(self, root):
        """
        One step left and then always right
        """
        root = root.left
        while root.right:
            root = root.right
        return root.val

    def deleteNode(self, root: TreeNode, key: int) -> TreeNode:
        if not root:
            return None

        # delete from the right subtree
        if key > root.val:
            root.right = self.deleteNode(root.right, key)
        # delete from the left subtree
```

Complexity Analysis

- Time complexity : $\mathcal{O}(\log N)$. During the algorithm execution we go down the tree all the time - on the left or on the right, first to search the node to delete ($\mathcal{O}(H_1)$ time complexity as already discussed) and then to actually delete it. H_1 is a tree height from the root to the node to delete. Delete process takes $\mathcal{O}(H_2)$ time, where H_2 is a tree height from the root to delete to the leafs. That in total results in $\mathcal{O}(H_1 + H_2) = \mathcal{O}(H)$ time complexity, where H is a tree height, equal to $\log N$ in the case of the balanced tree.
- Space complexity : $\mathcal{O}(H)$ to keep the recursion stack, where H is a tree height. $H = \log N$ for the balanced tree.

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Preview Post

matugm ★ 18 April 26, 2019 6:09 PM
Execellent article!

@andvary Could you share what tool are you using to generate the binary tree pictures?

Thank you.
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iwfwcf ★ 28 May 3, 2019 8:16 PM
If delete node has only one child, just replace it with the only child would be enough. No need to find predecessor or successor.
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pooyax ★ 35 December 10, 2019 8:07 AM
It is my first time that I reading a solution without wrestling! And I am crying now! 😹😹😹
7 Share Reply

azimbabu ★ 137 December 26, 2019 9:02 AM
The solution seems to clone the value at successor or predecessor instead of actually moving either of them up the tree at all. An interviewer can reasonably argue that this is not actually deleting a node because the node remains in the tree with an updated value from either predecessor or successor.
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Miracle88 ★ 11 February 16, 2020 8:26 PM
How can we delete a node by doing this:
node = null.

We have to do this:
parent.right = null (if node is right child parent) or parent.left = null (if node is left child of parent).
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RogerFederer ★ 856 June 17, 2020 11:31 PM
Very clear explanation, easy to understand.
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huang226 ★ 1 April 14, 2020 10:09 AM
really good and logical article!
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denny2826 ★ 4 March 7, 2020 3:54 PM
This is great!
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nix_on ★ 54 February 19, 2020 3:25 AM
loved it!
1 Share Reply

rsrigiri ★ 1 February 2, 2020 10:09 AM
Thanks for the great explanation. Really helpful.
1 Share Reply

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