

Prog 2 Red-Black Trees

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Each node in a Red Black tree is just like in any BST has two children, where the left child is less than the parent, and the right child is greater. Each node is either red or black, the color represents the role in maintaining the tree's balance. The colors follow the given properties:

- **Root Property:** The root of the tree is always black.
- **External Property:** Every leaf (null child) is considered black.
- **Internal Property:** The children of a red node are always black. Thus, a red node cannot have a red parent or red children.
- **Depth Property:** All paths from a node to its descendant leaves must contain the same number of black nodes. This property ensures that the longest path from the root to any leaf is no more than twice as long as the shortest path.
- **Path Property:** No path can have two consecutive red nodes. This property ensures that the longest path from the root to any leaf has no more than one extra black node compared to the shortest path.

For insertion, when a node is inserted, it is initially colored to be Red to maintain properties. Then, if necessary, the tree is rebalanced to satisfy the properties.

For deletion, when a node is removed, it is replaced by its successor, the minVal of the right subtree. It is also rebalanced if necessary.

I read about insertions and deletions on [GeeksforGeeks](#).

Rotations are performed if necessary to rebalance the tree. I learned how to do these rotations through a YouTube video by Michael Sambol

Red Black trees combine binary search tree properties with the self-balancing properties to ensure balanced trees and efficient operations.

Order Of Magnitude for operations

Function	Order of Magnitude
Remove	$O(\log n)$
Insert	$O(\log n)$
fixDeleteViolation	$O(1)$
fixInsertViolation	$O(1)$
leftRotate	$O(1)$
rightRotate	$O(1)$
erase	$O(n^2)$
inOrderTraversal	$O(n)$

Citations

"Introduction to Red-Black Tree." GeeksforGeeks, GeeksforGeeks, Updated on 07 Feb. 2022, <https://www.geeksforgeeks.org/introduction-to-red-black-tree/>.

Michael Sambol. "Red-black trees in 3 minutes — Rotations." YouTube, uploaded by freeCodeCamp.org, 5 Aug. 2018, <https://www.youtube.com/watch?v=95s3ndZRGbk>.