Red Black Tree Deletion

Deletion Procedure in BST

1. Is the node (X) to be deleted a leaf node? Just delete
2. Is the node (X) to be deleted has one child node (Y), then swap the node X and Y and delete X.
3. Is the node (X) to be deleted has two child nodes (Y and Z), then do the following:
   ▶ Find the in order successor node recursively. (Left most child in right subtree)
   ▶ Swap nodes, and delete the leaf node.
So what is different in RB Tree Deletion

1. Red parent with red child violation may happen
2. Double black node (a node $X$ with parent $Y$), may lead to different number of black nodes on the different paths in the tree.
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RB Tree Deletion Fix

1. Case by case approach
2. Recoloring and Rotation
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RB Tree Deletion Base Case

1. Apply BST deletion procedure
2. If the node (X) to be deleted is a red node, just delete it
3. If the node (X) to be deleted is a black node, with a red child node (Y), then delete X and recolor Y into black node.
4. If the node (X) to be deleted is a double black node, then there are a total of 6 different cases to fix the RB violation.
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RB Tree Double Black Node Fix
There is two categories of Fix to resolve the double black node violation in a Red Black tree:

1. Terminal node fix (Case 1, 2, and 3): This leads to a immediate fix by applying the rules associated with the case.
2. Non Terminal node fix (Case 4, 5, 6): This does not lead to a immediated fix by applying the rules associated with the case. Instead it will delegate the violation to the upper level nodes and thereby we need to try other cases iteratively to fix the issue.
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We will discuss double black node fix on Wednesday class.

Class activity

1. Use the BST tree visualization tool provided below:
   https://www.cs.usfca.edu/galles/visualization/BST.html
2. Use the red black tree visualization tool provided below:
   https://www.cs.usfca.edu/galles/visualization/RedBlack.html
3. Try at least three different BST tree variations delete, which is a base case violation. First do the insert.
4. Try at least three different Red black tree variations delete, which is a base case violation. First do the insert.
5. Post your solution in Slack.