Red-black Tree notes

Prof Bill, Mar 2020

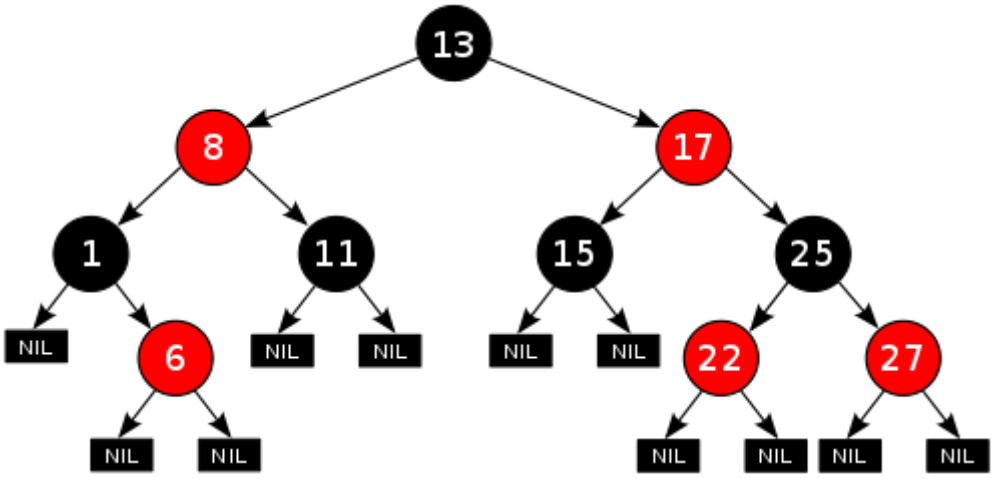
Wikipedia goodness: en.wikipedia.org/wiki/Red%E2%80%93black_tree

Read: Sedgewick Algorithms 3.3 Balanced Search Trees,
algs4.cs.princeton.edu/33balanced

Animation: Select “Red-Black Trees”; great animation!
www.cs.usfca.edu/~galles/visualization/Algorithms.html

The red-black rules are:

- ❏ Each node is either red or black.
- ❏ The root is black.
- ❏ All leaves (NIL) are black.
- ❏ If a node is red, then both its children are black.
- ❏ Every path from a given node to any of its descendant NIL nodes contains the same number of black nodes.



Some pseudocode for inserting nodes:

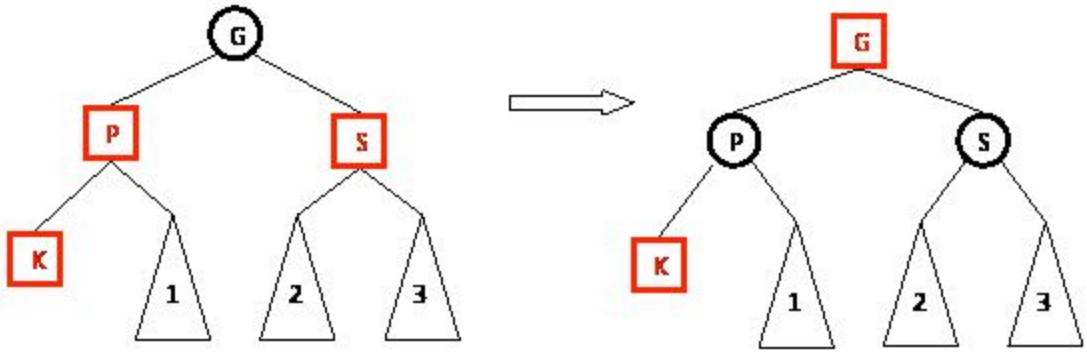
```
      insert( K key)
          n = create red node( key)
          if empty tree
              root = n
              change n color to black
          else
              do BST insert of n as leaf
              if parent of n is red
                // new node and its parent are both red = must fix
this!
                if uncle of n is red, then recolor
                else rotate
```

Recoloring

In the figure below… a new node (K) is added. It's parent (P) is red causing a red-red violation. If the uncle (S) is red, then recolor in two steps:

1. Make the grandparent (G) red, and
2. Color its children (P and S) black.

This resolves the red-red conflict AND maintains equal black-height.



Important - making the red grandparent (G) may cause a conflict above us. Apply the same recursively to grandparent (G).

Rotation

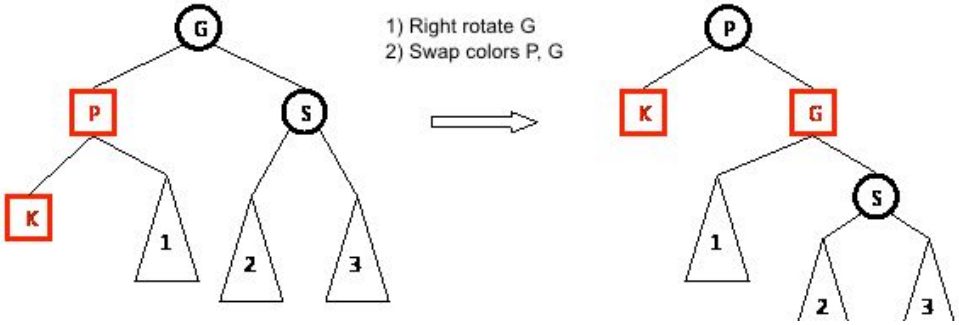
If the new node's uncle is a black node, then rotation is required.

There are 4 rotations cases (similar to AVL). They're on the next back (the back).

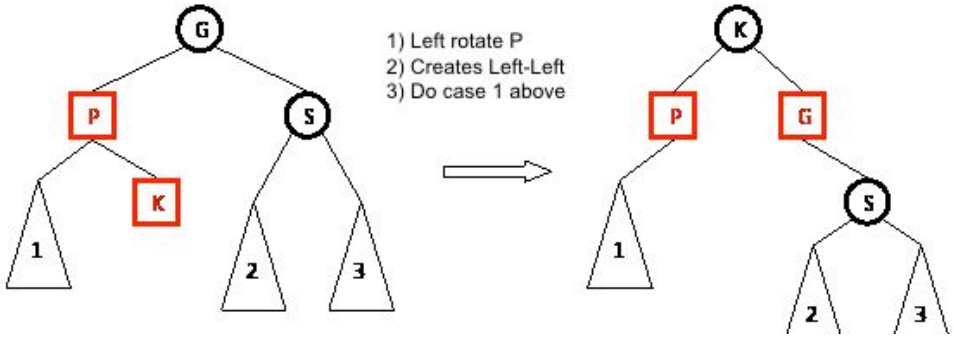
Source: pages.cs.wisc.edu/~paton/readings/Red-Black-Trees/

4 Rotation cases - when a new node (K) has a red parent (P) and a black uncle (S).

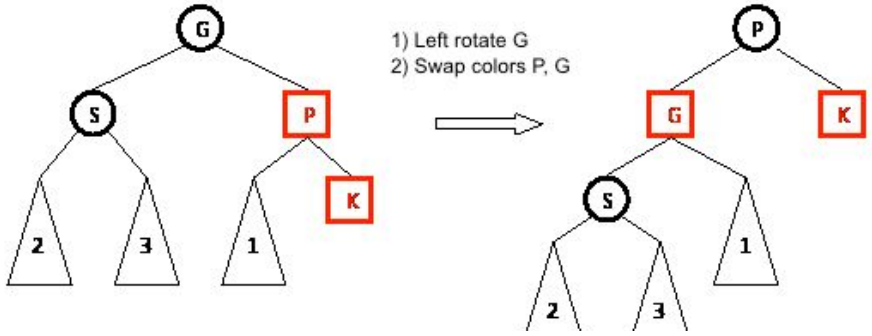
Case 1: Left-Left (P is parent, K is new (Key) node)



Case 2: Left-Right



Case 3: Right-Right



Case 4: Right-Left