CMPSC 250

Analysis of algorithms

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Red Black Trees

Unbalanced Tree Structure
Red Black Trees

2-3 BST

Too much balancing act, thereby certain insert takes longer.
Red Black Trees

Structure

- A red-black tree is a balanced BST
- Each node has an extra color field which is red or black, Usually represented as a boolean isBlack
Red Black Trees

Balancing Nodes

- Recoloring - change colors of the node
- Rotation - rotate left or rotate right to make the tree balanced.
Red Black Trees

Left Rotation

```
       x
      /|
     y  z
    /  /|
   A   B  C  D
```
Left Rotation
Red Black Trees

Right Rotation
Red Black Trees

Right Rotation

Diagram:
- Node X
- Node Y
- Node Z
- Node A
- Node B
- Node C
- Node D

Arrow indicates the direction of the right rotation.
Red Black Trees

Left Rotation Example

```
  47
 /   \
32    81
 /     /
13  40  44
   /
  37
```
Left Rotation Example

- Rotate 32 Left
Right Rotation Example
Red Black Trees

Right Rotation Example

- Rotate 47 Right
  on board - make notes
Red Black Trees

Red Black Tree Insertion

New node inserted as Red

Insert 65
Red Black Trees

Red Black Tree Insertion - Case 1 Fix

- If parent and uncle are both red Then colour them black
- And colour the grandparent red
- It must have been black beforehand, why?
Red Black Tree Insertion

Insert 65
Insert 82

Red Black Trees
Red Black Tree Insertion - Case 1 Applied

Insert 65
Insert 82

change nodes’ colours
Red Black Trees

Red Black Tree Insertion - Case 2 Fix

- If parent is red but uncle is black
- Need to do some tree rotations to fix it
Red Black Tree Insertion - Case 2 Applied

Insert 65
Insert 82
Insert 87
Red Black Trees

Red Black Tree Insertion - Case 2 Applied

- Insert 65
- Insert 82
- Insert 87

Diagram:

- Root: 47
- Left child: 32
- Right child: 71
  - Left child: 65
  - Right child: 93
    - Left child: 82
      - Right child: 87
Red Black Tree Insertion - Case 2 Applied

Insert 65
Insert 82
Insert 87
Red Black Tree Insertion - Case 2 Applied

Insert 65
Insert 82
Insert 87

change nodes’ colours
Red Black Trees

Red Black Tree Insertion - Case 2 Applied

- Insert 65
- Insert 82
- Insert 87
Red Black Trees

Textbook Reading

432 - 440
Class Activity - Post in slack or email

Exercise 3.3.14 in textbook. Insert Letters A through K in Red Black Tree. What happens when the tree is in ascending order.