Data Structures & Algorithms
(PCC-CS 301)

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Topics Covered

1. AVL tree: data deletion
2. Advantage & disadvantage of AVL tree
3. Introduction to Red-black tree

AVL Tree

- Data deletion
  - Data deletion in AVL tree is similar as BST
  - After deletion, check the Balance Factor of each node
  - If any node holds BF out of range i.e BF < -1 or BF > 1
  - Trace the unbalanced node scanning from the bottom of the tree
  - Apply any of the following rotations on the unbalanced node
    - R0 rotation (similar to LL rotation)
    - R1 rotation (similar to LL rotation)
    - R-1 rotation (similar to LR rotation)
    - L0 / L1 / L-1 (mirror image of R0 / R1 / R-1)

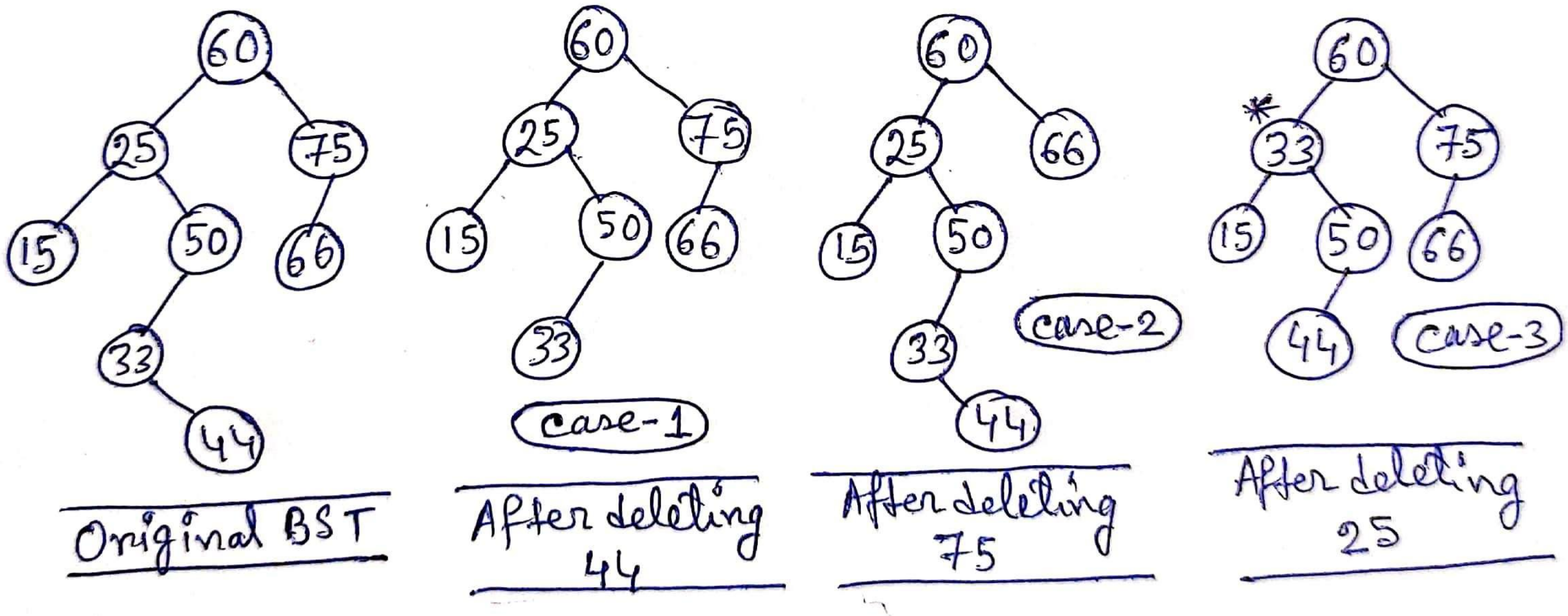
AVL Tree

- Data deletion in BST

  - If we want to delete a node **X**
    - **X** has no children, simply remove **X** from the tree (**case-1**)
    - **X** has exactly one child, replace **X** with its only child (**case-2**)
    - **X** has two children, delete **in-order successor** of **X** from the tree by following any of the above steps and replace the data with **X** (**case-3**)

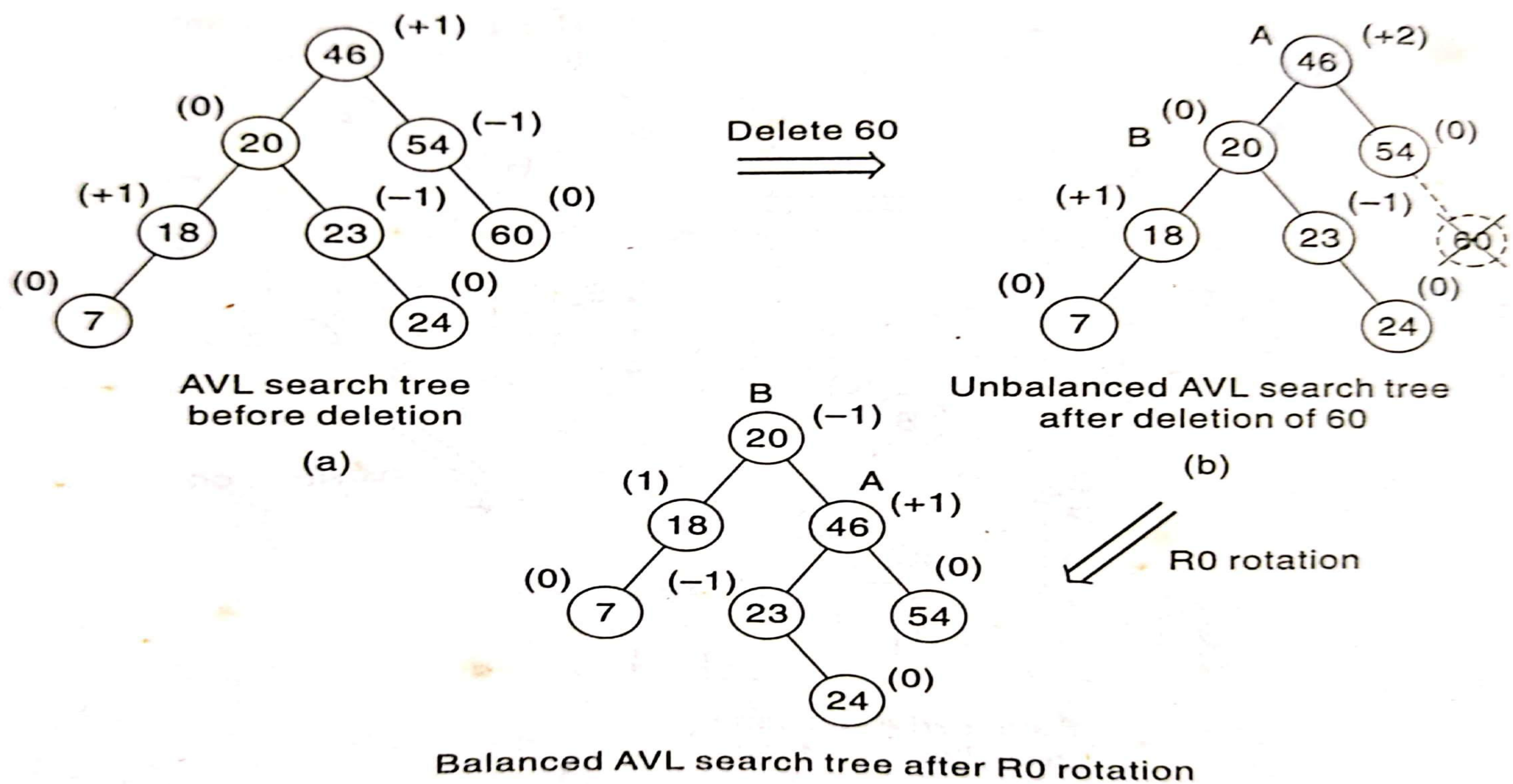
AVL Tree

- Data deletion in BST



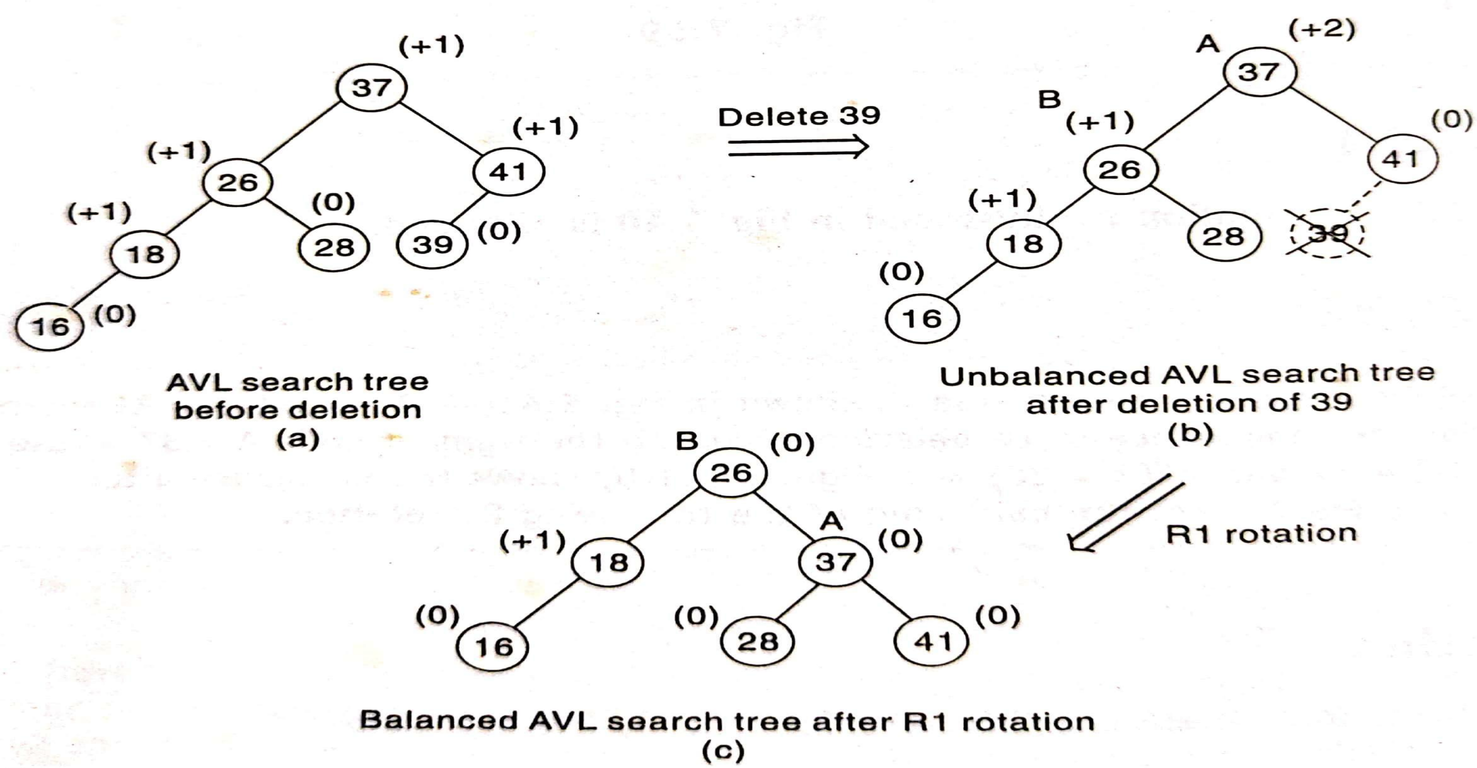
AVL Tree

- Data deletion
  - **R0 rotation :** if node B has balance factor 0



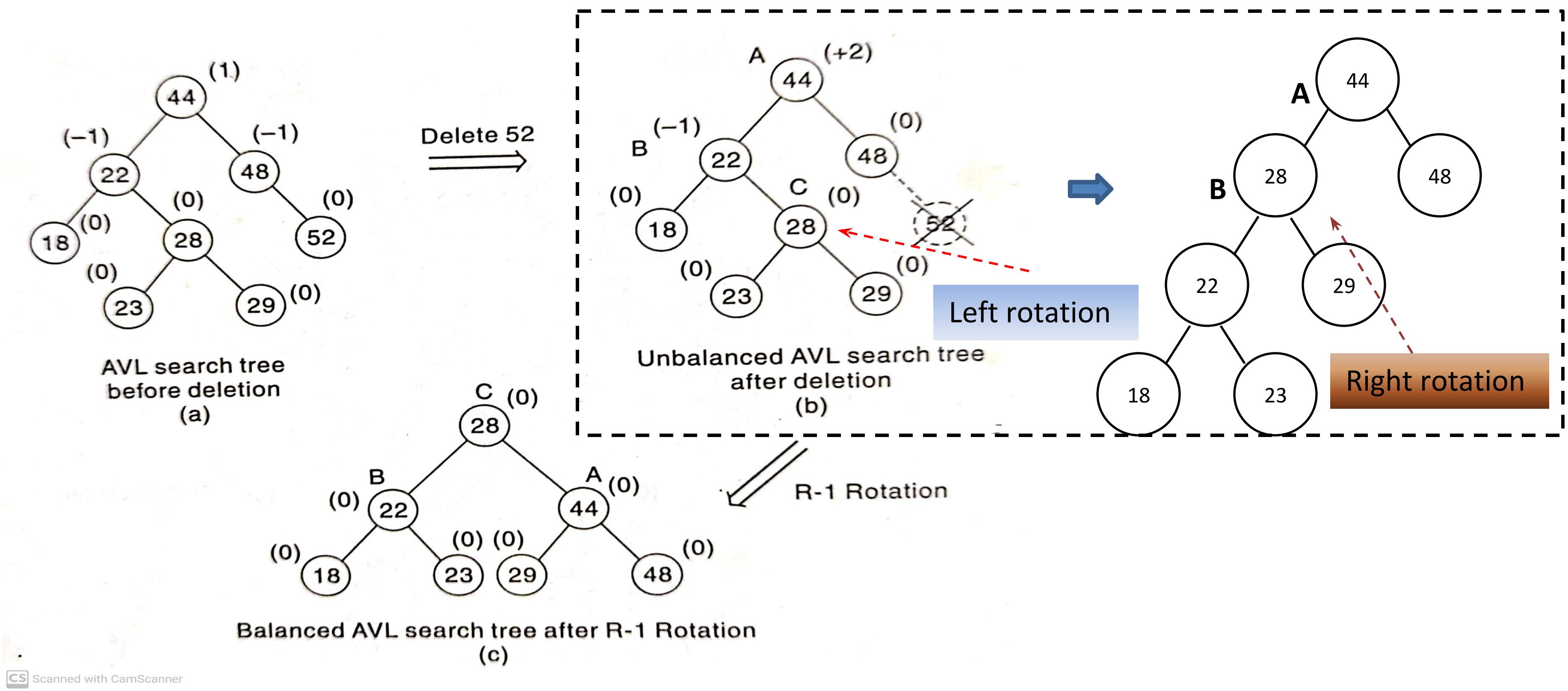
AVL Tree

- Data deletion
  - **R1 rotation:** if node B has balance factor 1



AVL Tree

- Data deletion
  - **R-1 rotation:** if node B has balance factor -1



AVL search tree before deletion (a)

Unbalanced AVL search tree after deletion (b)

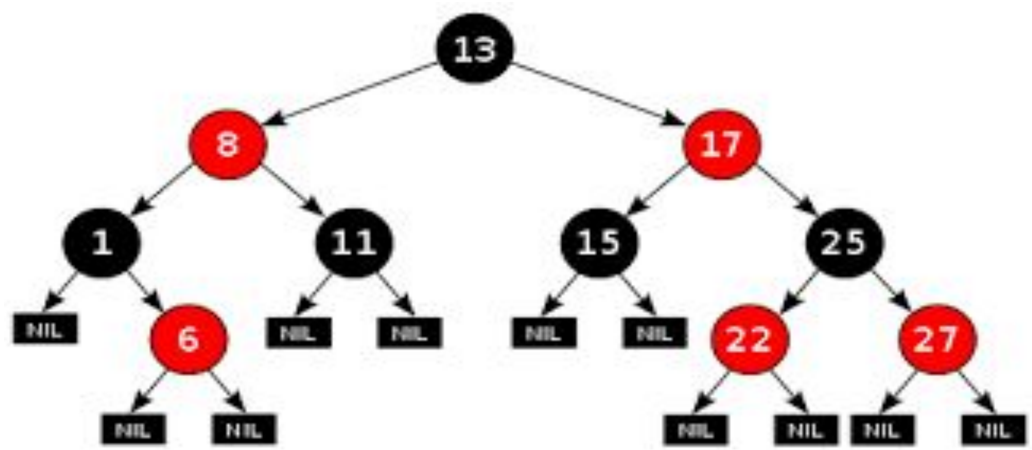
Balanced AVL search tree after R-1 Rotation (c)

AVL Tree

- Advantage
  - Data searching can be done in lesser time than BST
  - As AVL tree maintains balanced height, searching time complexity $O(\log_2 n)$ as the maximum height $\log_2 n$
- Disadvantage
  - Operations like insertion and deletion is critical
  - It may require rotation to be performed on each insertion and deletion of data
- To overcome the data manipulation complexity, Red-Black tree is preferred

Red-black Tree

- Property
  - Every node is either Red or Black
  - The Root is Black
  - Every leaf (NIL) is Black
  - If a node is Red, both its children are Black
  - For each node, all simple paths from the node to descendant leaves contain the same number of black nodes



Binary Height Balanced Tree

- Application
  - If any application involves many frequent insertions and deletions, then Red Black trees should be preferred
  - If the insertions and deletions are less frequent and search is the more frequent operation, then AVL tree should be preferred as AVL is more balanced than Red-Black tree
  - AVL tree is used in Memory management subsystem of linux kernel to search memory regions of processes during preemption
  - In railway or airways, to display the train/flight timings on the display board will be convenient if the data stored using AVL search tree as the new entry (or deletion) of train/flight may be very infrequent in the database

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Queries?

Problem

Q1. Consider the following data that need to be inserted in an AVL tree

Data set: { 25, 40, 15, 10, 6, 28, 32, 35, 50, 5, 12, 8, 10, 38, 3, 45 }

Q2. Delete the following set of data from the previously maintained AVL data structure

{ 25, 6, 50, 5, 3, 45 }