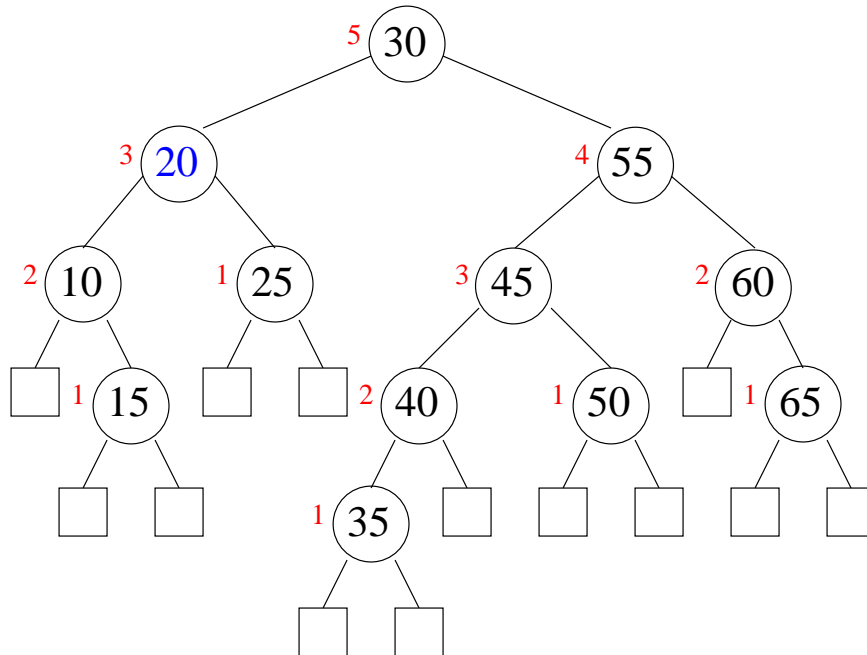


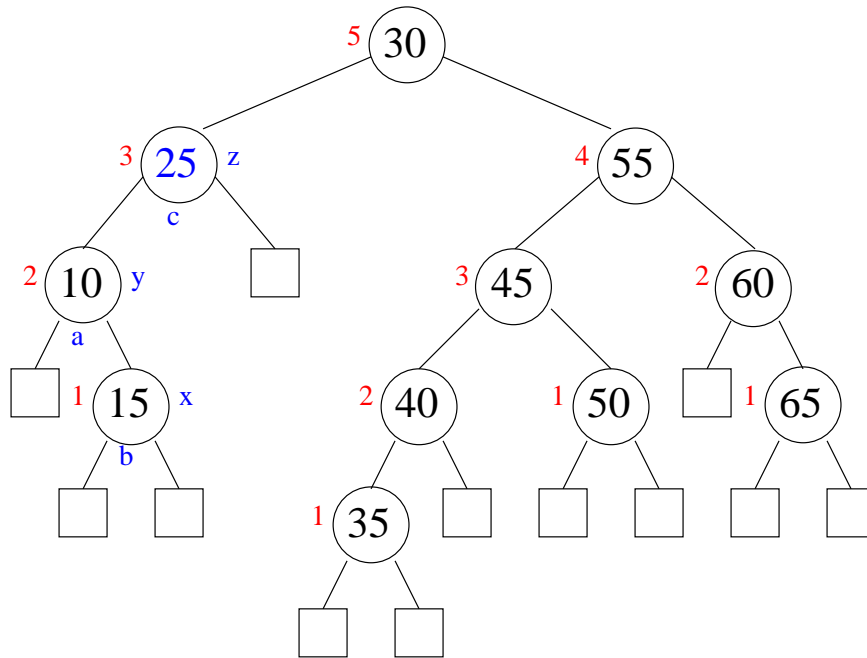
## Complex AVL Tree Deletion Example

- Original AVL tree:



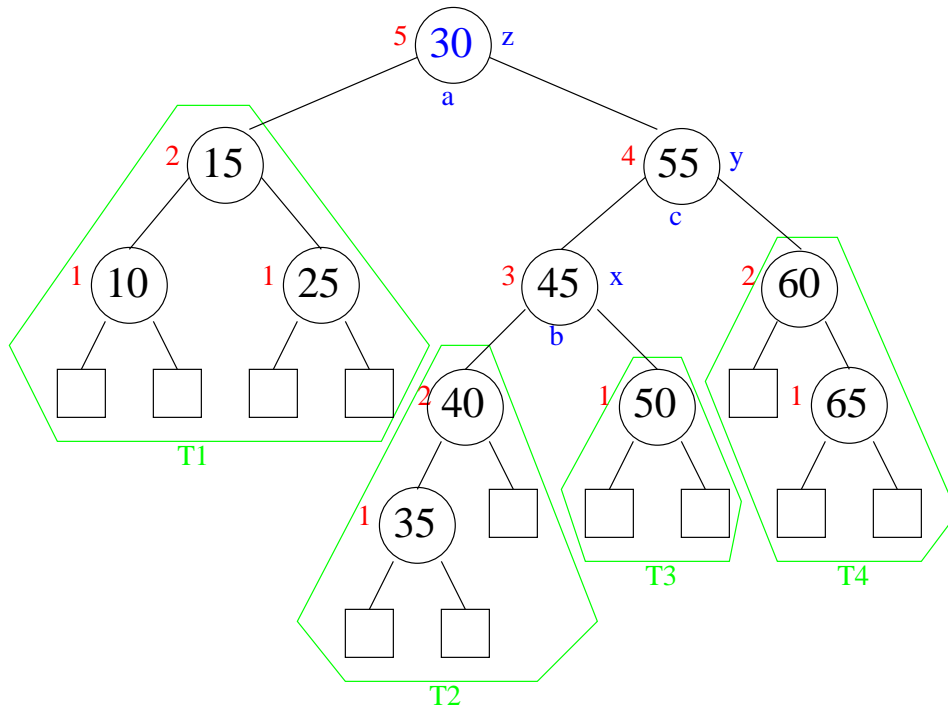
- External nodes have height 0; internal nodes have height labelled in red to their left
- Original AVL tree is indeed balanced
- Say we had the above tree, and want to delete key 20
- To delete key 20:
  - Move key 25 up to where key 20 is
  - Delete the node that used to contain 25

## Next Step



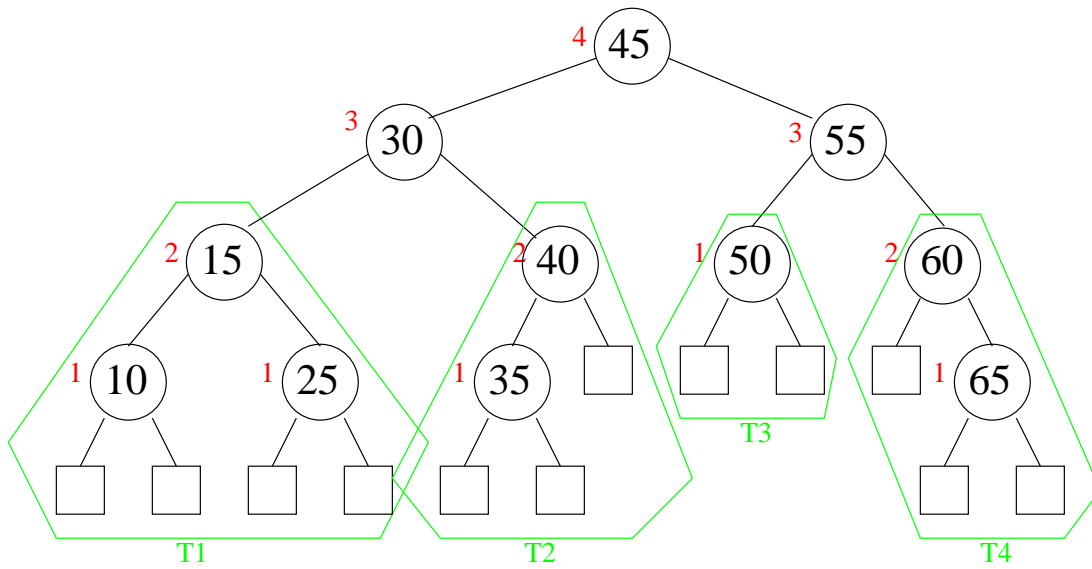
- Now the tree is unbalanced at the node containing 25
  - Left subtree has height 2
  - Right subtree (just one external node) has height 0
- Must restructure
  - Label nodes **z**, **y**, **x** from unbalanced node down to grandchild causing the problem
  - Relabel those nodes **a**, **b**, **c** going through those nodes in inorder traversal
  - The four other trees are just external nodes
  - As always, move **b** up to where unbalanced node was

## Next Step



- Now the tree is unbalanced at the root (the node containing 30)
  - Left subtree has height 2
  - Right subtree has height 4
- Must restructure again
  - Label nodes  $z$ ,  $y$ ,  $x$  from unbalanced node down to grandchild causing the problem
  - Relabel those nodes  $a$ ,  $b$ ,  $c$  going through those nodes in inorder traversal
  - The four other trees are  $T1$ ,  $T2$ ,  $T3$ ,  $T4$  as shown
  - As always, move  $b$  up to where unbalanced node was

## Last Step



- Balanced