

Chapter 43 Red Black Trees

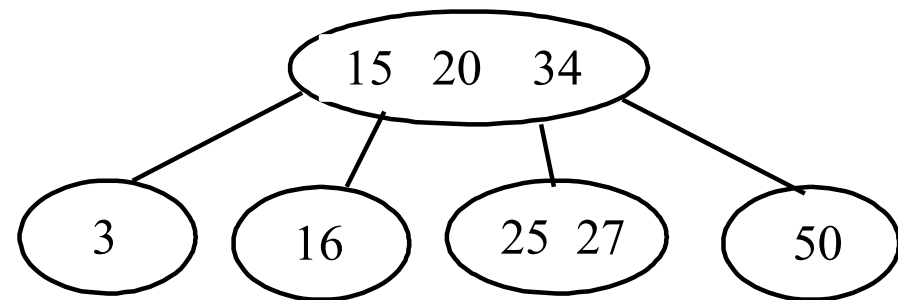
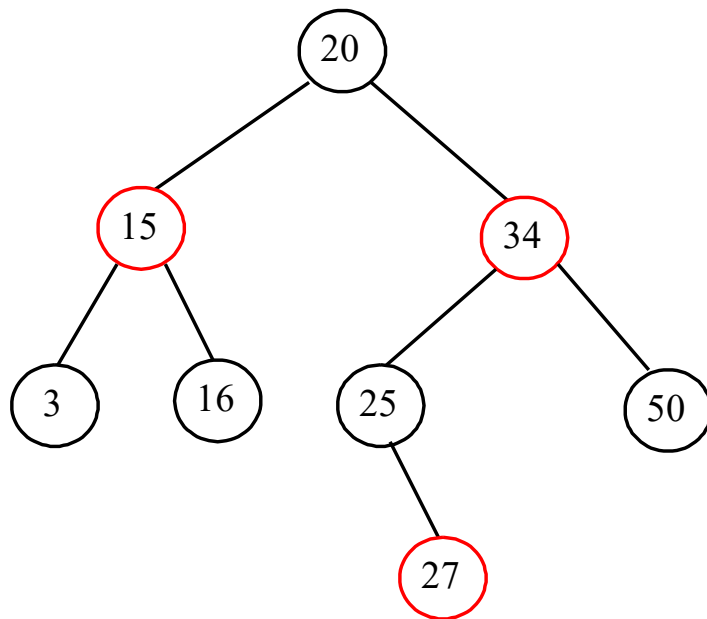


Objectives

- ♦ To know what a red-black tree is (§43.1).
- ♦ To convert a red-black tree to a 2-4 tree and vice versa (§43.2).
- ♦ To design the RBTree class that extends the BinaryTree class (§43.3).
- ♦ To insert an element in a red-black tree and resolve the double red problem if necessary (§43.4).
- ♦ To insert an element from a red-black tree and resolve the double black problem if necessary (§43.5).
- ♦ To implement and test the RBTree class (§§43.6-43.7).
- ♦ To compare the performance of AVL trees, 2-4 trees, and RBTree (§43.8).

What is a Red Black Tree?

A red-black tree is a binary search tree, which is derived from a 2-4 tree. A red-black tree corresponds to a 2-4 tree. Each node in a red-black tree has a *color attribute* red or black.



What is a Red Black Tree?

A node is called *external* if its left or right subtree is empty. Note that a leaf node is external, but an external node is not necessarily a leaf node. For example, node 25 is external, but it is not a leaf. The *black depth* of a node is defined as the number of black nodes in a path from the node to the root. For example, the black depth of node 25 is 2 and the black depth of node 27 is 2.



Properties

A red-black tree has the following properties:

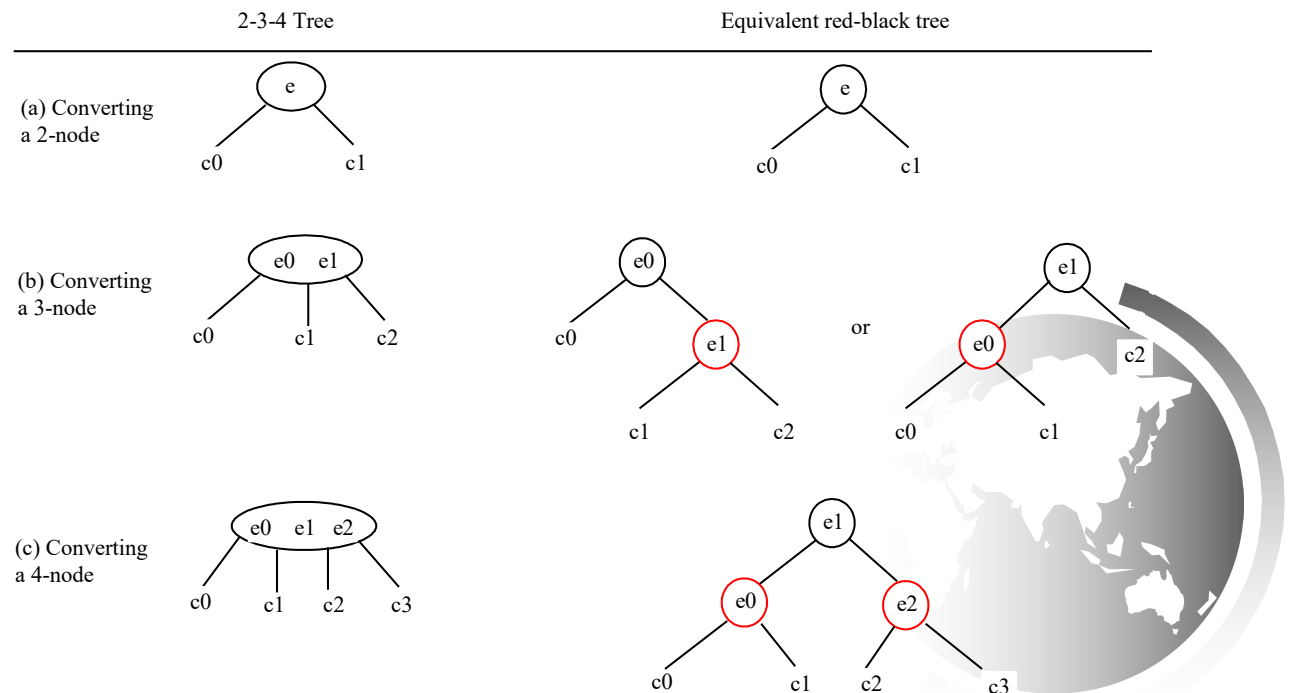
- The root is black.
- Two adjacent nodes cannot be both red.
- All external nodes have the same black depth.



Conversion between Red-Black Trees and 2-4 Trees

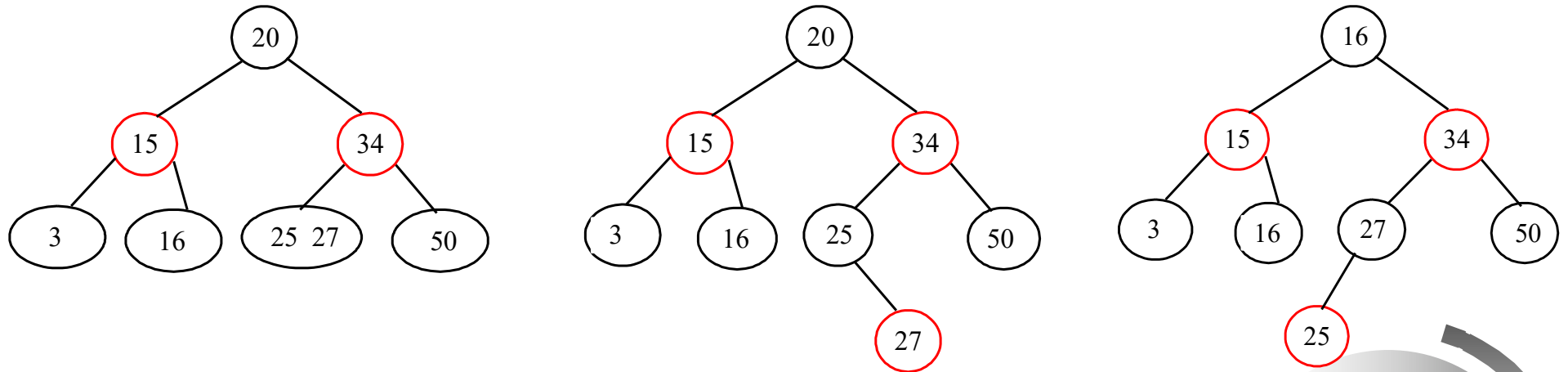
To convert a red-black tree to a 2-4 tree, simply merge any red nodes with its parent to create a 3-node or a 4-node.

To convert a 2-4 tree to a red-black tree, perform the transformations for each node :



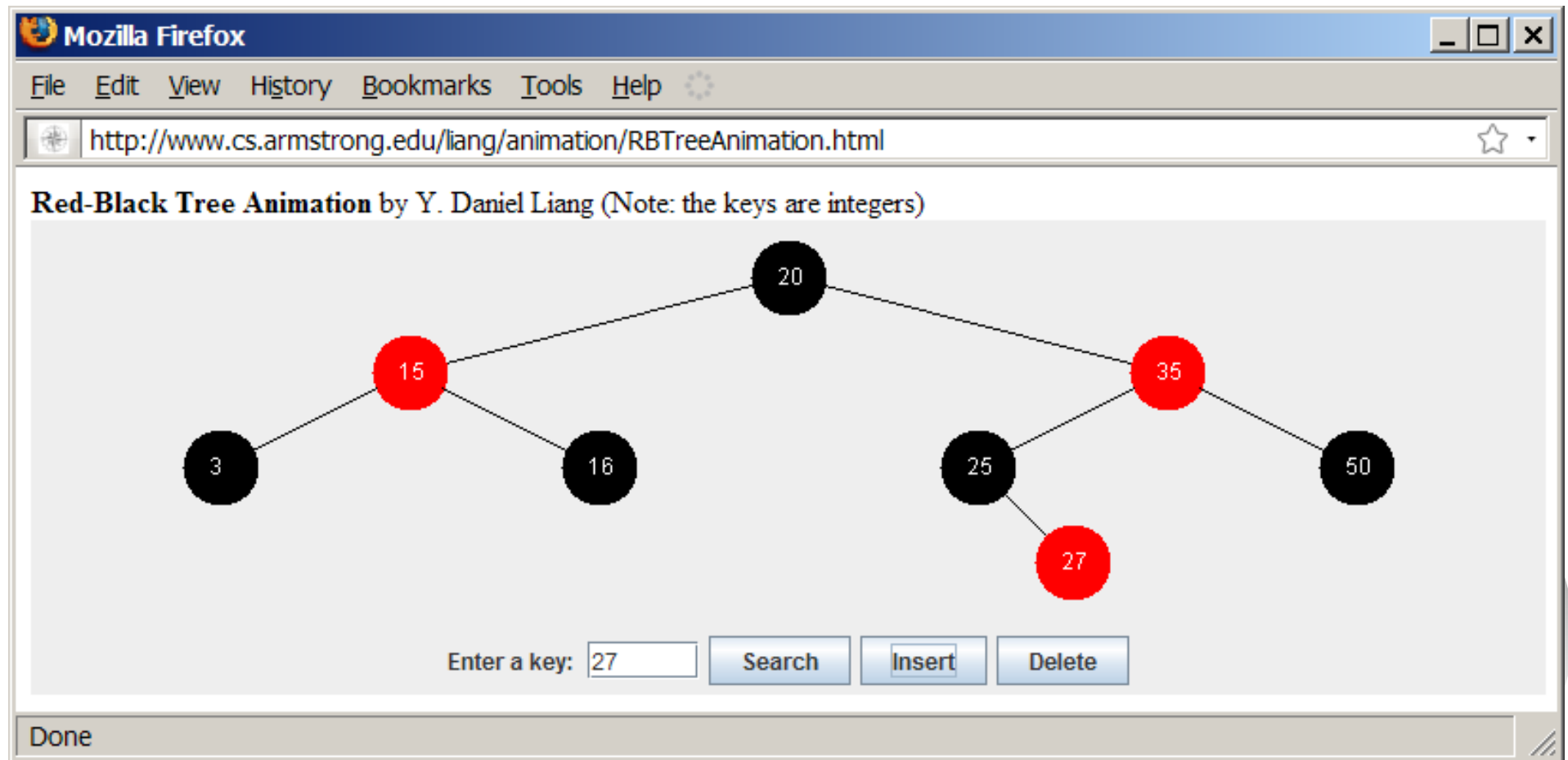
Conversion not unique

the conversion from a 2-4 tree to a red-black tree is *not unique*.

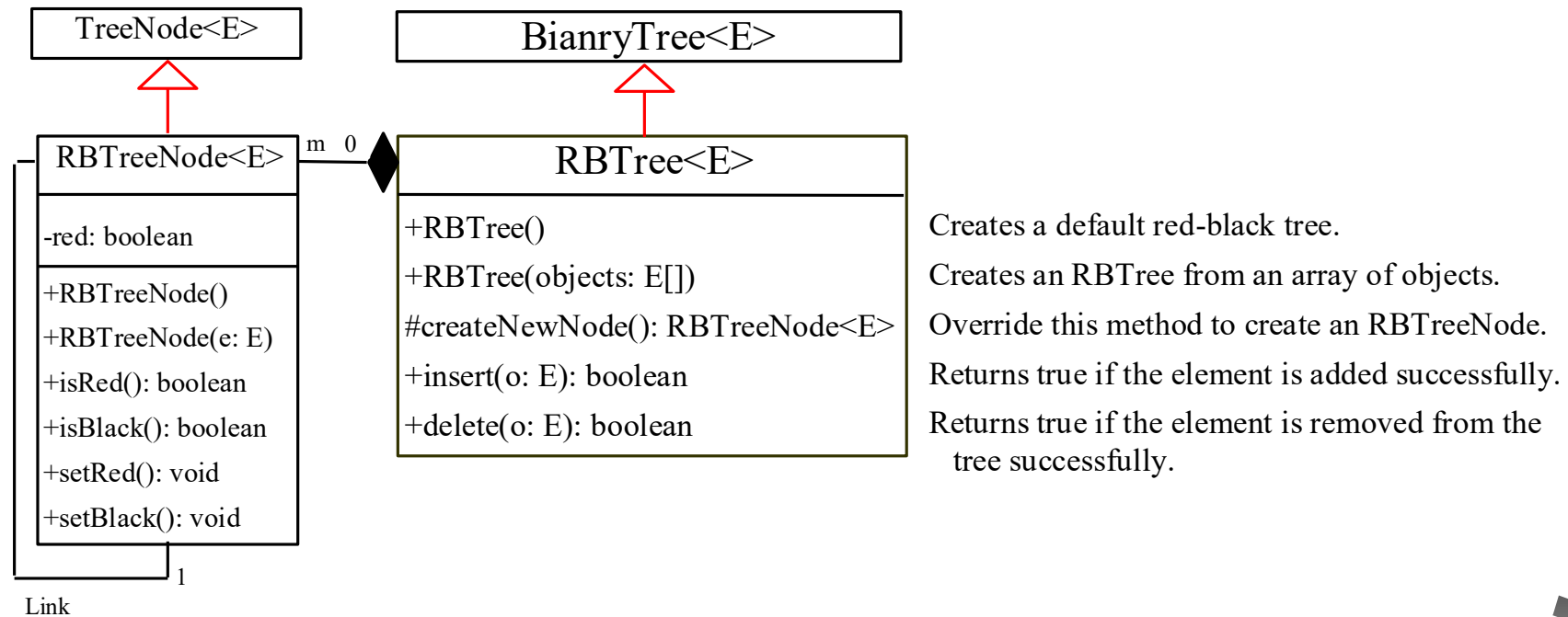


2-4 Tree Animation

<http://www.cs.armstrong.edu/liang/animation/RBTreeAnimation.htm>
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Designing Classes for Red Black Trees



Creates a default red-black tree.

Creates an RBTree from an array of objects.

Override this method to create an RBTreeNode.

Returns true if the element is added successfully.

Returns true if the element is removed from the tree successfully.

RBTree

TestRBTree