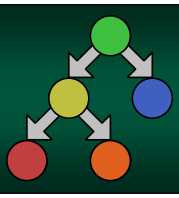
Binary Search Trees

Part 10

1



Binary Search Trees

Climbing a tree has never been so fun

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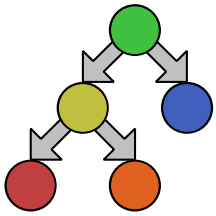
Binary Search Trees

- *Binary Search Tree (BST)* is a special type of binary tree that sorts nodes by value
- For each node…
  - all the nodes on the left branch are less than it
  - all the nodes on the right branch are greater than it



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Searching the Tree

- Since the tree divides the problem progressively by two, the time complexity is only O(log n)
- Which gives that all the benefits of a sorted array
- Worst case is O(n) – if the tree is a list-like chain

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Search logic (looking for S)

- Looking for If *S* is equal to the current node, you found it
- If *S* is smaller than the current node, take the left branch
- If *S* is bigger than the current node, take the right branch
- If there are no branches, *S* was not found

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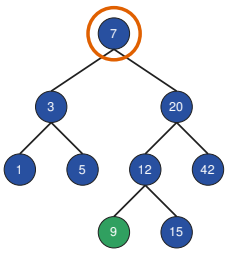
Searching for 9



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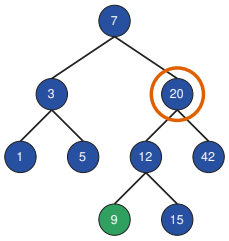
Searching for 9



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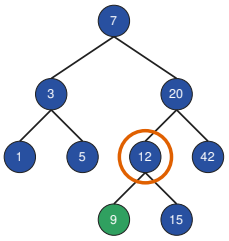
Searching for 9



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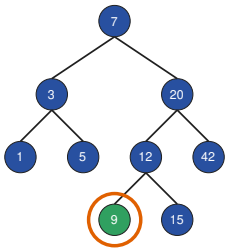
Searching for 9



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Inserting into the Tree

- Inserting is handled exactly like a search
- The only difference is that if the item is not found, the node is added
- If we reach a leaf…
  - we are already at the max-depth of the tree
  - we are at the node that needs to be updated
  - so, add a left or right node (based on value)
  - … wow, this is easy!

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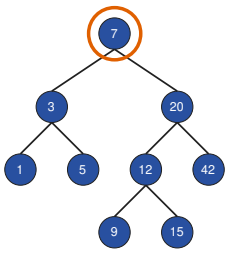
Inserting 4



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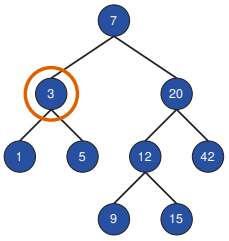
Inserting 4



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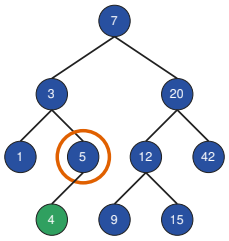
Inserting 4



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Binary Search Trees vs. Arrays

- Insert into a Binary Search Tree
  - traverses down the tree
  - then add itself as a leaf
  - it requires only **O(log n)**
- Insert into an Array
  - must expanded when new elements are added
  - …and compacted when elements are removed
  - these requires **O(n)**

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Deleting From a BST

Not as easy as Heaps

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Deleting From a BST

- Deleting from a BST is a tad more tricky
- When the node is deleted, the tree needs to be re-linked to *still preserve the ordering*

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Deleting From a BST

- Fortunately, while the logic might seem a tad hard, it is fairly straight forward
- There are 3 different scenarios that must be taken into account based on the node being deleted

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Case 1: The Node is a Leaf

- If the node (to be deleted) is a leaf, it can simply be removed from the parent
- This is due to, the fact that, nothing is linked from the node

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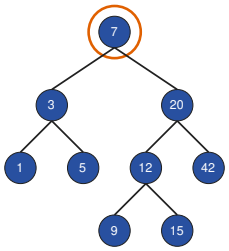
Case 1: Deleting 5



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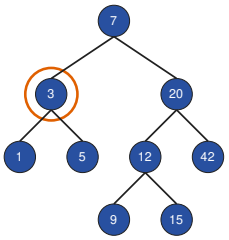
Case 1: Deleting 5



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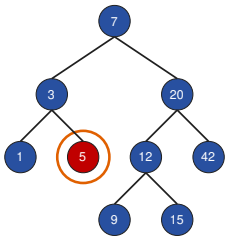
Case 1: Deleting 5



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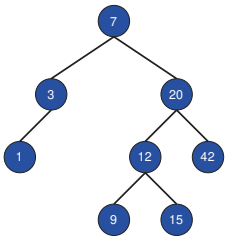
Case 1: Deleting 5



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Case 2: One Child

- If the deleted node has a single child, then that child can be *"promoted"*
- The deleted node's child is moved into its position
- … so, the subtree moves into the space created by the deleted node

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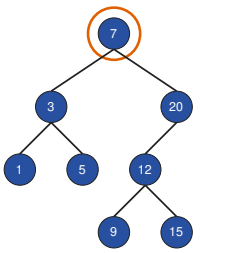
Case 2: Deleting 20



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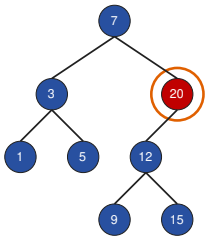
Case 2: Deleting 20



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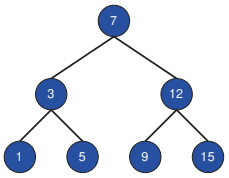
Case 2: Deleting 20



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Case 3: Two Children

- However, if the deleted node has two children, then things get a tad more complex
- We need to find a node to *"promote"* to the deleted node's position

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Case 3: Two Children

- We need to find a value that is mathematically next to the deleted value
- There are two equally valid options
- Choose one:
  - find the maximum node of the left (smaller) branch
  - … or find the minimum node of the right (larger) branch

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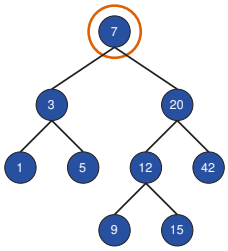
Case 3: Deleting 20



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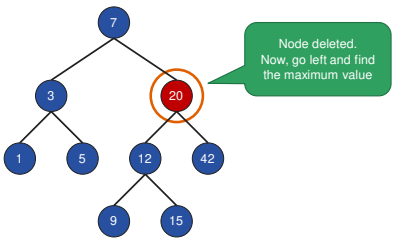
Case 3: Deleting 20



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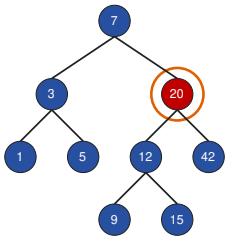
Case 3: Deleting 20 (Going Left)



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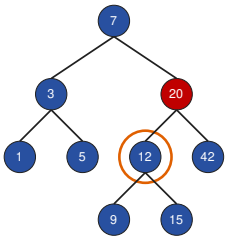
Case 3: Deleting 20 (Going Left)



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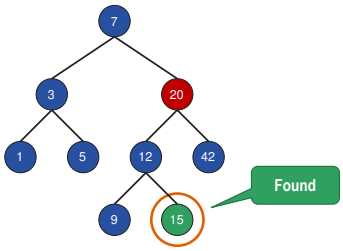
Case 3: Deleting 20 (Going Left)



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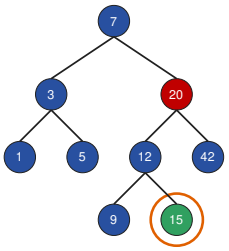
Case 3: Deleting 20 (Going Left)



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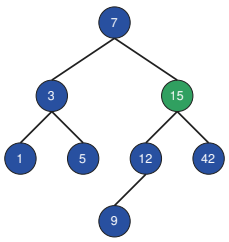
Case 3: Deleting 20 (Going Left)



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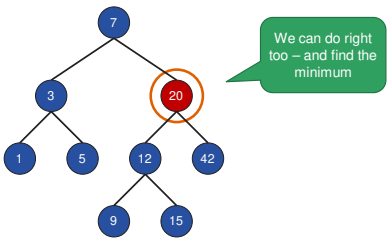
Deleting 20 : Going Right



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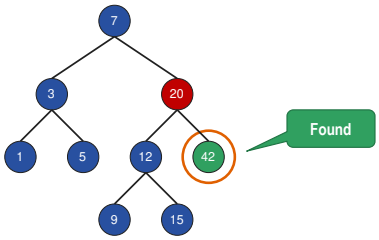
Deleting 20 : Going Right



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The Problem with BSTs

Climbing a tree has never been so fun

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The Problem with BSTs

- In a BST, internal nodes never change – and have a profound affect on the rest of the tree
- There are cases where the tree is unbalanced – one particular path contains most of the data

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The Problem with BSTs

- This can easily occur of the data is not truly random (which is generally the case)
- When this happens, **the time complexity slowly deteriorates to O(n)**

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Let's Try Adding…

- Let's add the following number to a binary search tree
- How did this tree look?

7, 8, 21, 43, 76

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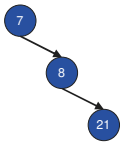
Let's add: 7, 8, 21, 43, 76

42

Let's add: 7, 8, 21, 43, 76

43

Let's add: 7, 8, 21, 43, 76



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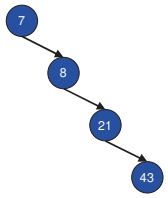
Let's add: 7, 8, 21, 43, 76



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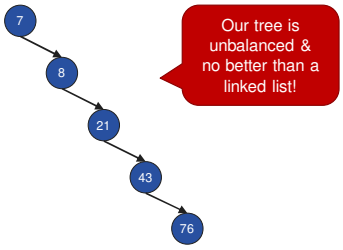
Let's add: 7, 8, 21, 43, 76



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Sort in a Binary Search Tree?

- Unfortunately, while this might seem like a good idea, this is not a great solution
- Binary Search Trees can deteriorate into linked lists
- So…
  - O(log n) search can quickly deteriorate to O(n)
  - …and O(n log n) sort can deteriorate to $O(n^2)$

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