CSC148-Section:L0301 Week#8-Friday

Instructed by

AbdulAziz Al-Helali

a.alhelali@mail.utoronto.ca

Office hours: Wednesday 11-1, BA2230.

Slides adapted from Professor Danny Heap course material winter17

Computer Science
UNIVERSITY OF TORONTO

Outline

- Binary Tree
  - Find – tracing
  - Traversal
- Binary Search Tree

Find - revisited

```
def find(node: Union[BinaryTree, None], data: object)-> Union[BinaryTree, None]:
    """
    Return BinaryTree containing data or else None.

    >>> find(None,15) is None
    True
    >>> bt = BinaryTree(5, BinaryTree(4),BinaryTree(3))
    >>> find(bt,7) is None
    True
    >>> find(bt,4)
    BinaryTree(4, None, None)
    >>> find(bt,3)
    BinaryTree(3, None, None)
    """
    if node is None:
        return None
    else:
        if node.value == data:
            return node
        elif find(node.left,data) is not None:
            return find(node.left,data)
        else:
            return find(node.right, data)
```

Find – another solution

```
def find(node: Union[BinaryTree, None], data: object)-> Union[BinaryTree, None]:
    """
    Return BinaryTree containing data or else None.

    >>> find(None,15) is None
    True
    >>> bt = BinaryTree(5, BinaryTree(4),BinaryTree(3))
    >>> find(bt,7) is None
    True
    >>> find(bt,4)
    BinaryTree(4, None, None)
    >>> find(bt,3)
    BinaryTree(3, None, None)
    """
     if node is None:
         return None
     else:
         if node.value == data:
             return node
         elif find(node.left,data) is not None:
             return find(node.left,data)
         elif find(node.right,data) is not None:
             return find(node.right,data)
         else:
             return None
```

If we add the following print in find:

```
print('node:', node.value if node is not None else "None")
if node is None:
    return None
else:
    if node.value == data:
        return node
    elif find(node.left,data) is not None:
        return find(node.left,data)
    elif find(node.right,data) is not None:
        return find(node.right,data)
    else:
        return None
```

What will be the output of this code?

```
from binary_tree_wed import *

bt3 = BinaryTree(3, None,BinaryTree(6))
bt2 = BinaryTree(4, BinaryTree(0),BinaryTree(8))
bt1 = BinaryTree(5, bt2,bt3)

print (find(bt1,7))
```

The output is:

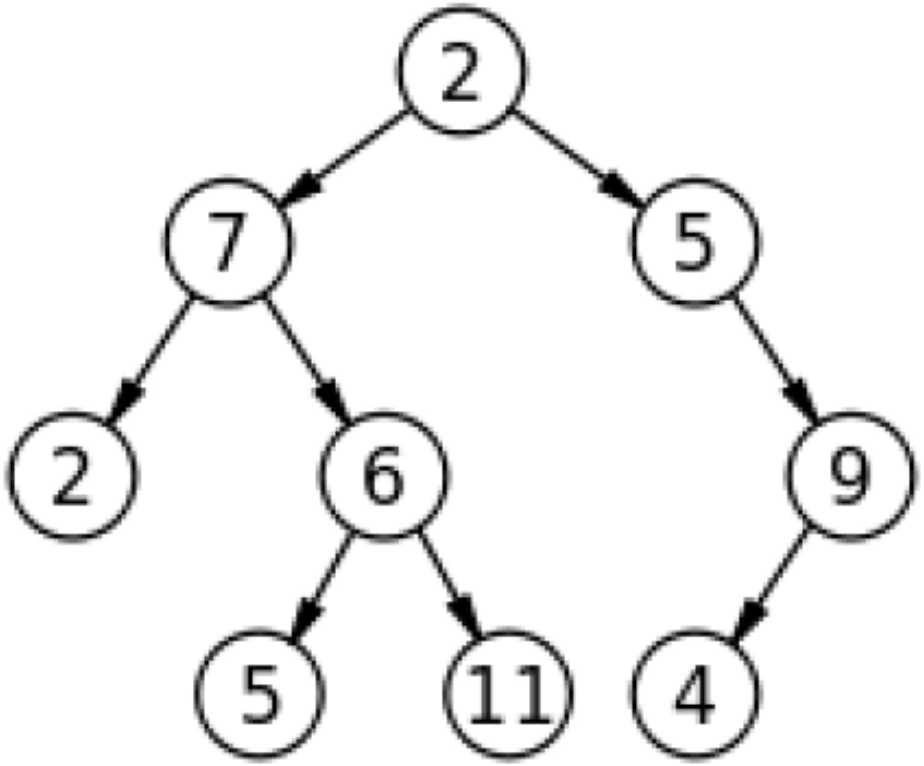
```
node: 5
node: 4
node: 0
node: None
node: None
node: 8
node: None
node: None
node: 3
node: None
node: 6
node: None
node: None
None
```

Tree traversal

-Preorder: visit parents first then children

-Postorder: visit children then parents

-Levelorder: visit node in each level



Tree traversal

-**Preorder**: visit parents first then children

- One Use : can be used to make a copy of tree
- order: 2,7,2,6,5,11,5,9,4

-**Postorder**: visit children then parents

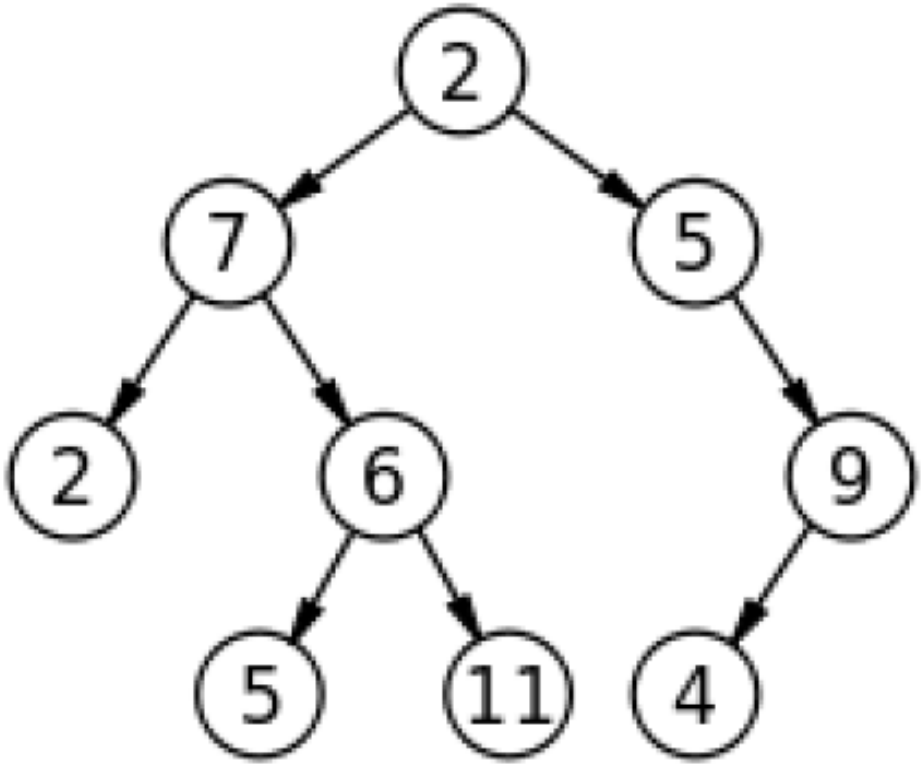
- One Use: can be used to delete tree
- order: 2,5,11,6,7,4,9,5,2

-**Levelorder**

- One Use : can be used to print a sorted tree
- order: 2,7,5,2,6,9,5,11,4

- Inorder

- One Use : in Binary Search Trees to print nodes in order
- 2,7,5,6,11,5,4,9



Binary Tree Traversal

- **We will implement the following functions:**
  - Preorder
  - Postorder
  - Inorder

preorder

- visit this node itself
- visit the left subtree in **preorder**
- visit the right subtree in **preorder**

```
def preorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit BinaryTree t in preorder and act on nodes as you visit.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> preorder_visit(bt, f)
    5
    7
    9
    """
```

```
def preorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit BinaryTree t in preorder and act on nodes as you visit.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> preorder_visit(bt, f)
    5
    7
    9
    """
    if t is None:
        pass
    else:
        act(t)
        preorder_visit(t.left, act)
        preorder_visit(t.right, act)
```

postorder

- visit the left subtree in **postorder**
- visit the right subtree in **postorder**
- visit this node itself

```
def postorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit BinaryTree t in postorder and act on nodes as you visit.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> postorder_visit(bt, f)
    7
    9
    5
    """
```

```
def postorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit BinaryTree t in postorder and act on nodes as you visit.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> postorder_visit(bt, f)
    7
    9
    5
    """
    if t is None:
        pass
    else:
        postorder_visit(t.left, act)
        postorder_visit(t.right, act)
        act(t)
```

inorder

- A recursive definition:
  - visit the left subtree **inorder**
  - visit this node itself
  - visit the right subtree **inorder**
- The code is almost identical to the definition.

```
def inorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit each node of binary tree rooted at root in order and act.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> inorder_visit(bt, f)
    7
    5
    9
    """
```

```
def inorder_visit(t: BinaryTree, act: Callable[[BinaryTree], Any]) -> None:
    """
    Visit each node of binary tree rooted at root in order and act.

    >>> bt = BinaryTree(5, BinaryTree(7), BinaryTree(9))
    >>> def f(node): print(node.value)
    >>> inorder_visit(bt, f)
    7
    5
    9
    """
    if t is None:
        pass
    else:
        inorder_visit(t.left, act)
        act(t)
        inorder_visit(t.right, act)
```

Binary Search Tree

- Add ordering conditions to a binary tree:
  - data are comparable: int, float, etc
  - data in left subtree are less than node.data
  - data in right subtree are more than node.data

Binary Search Tree

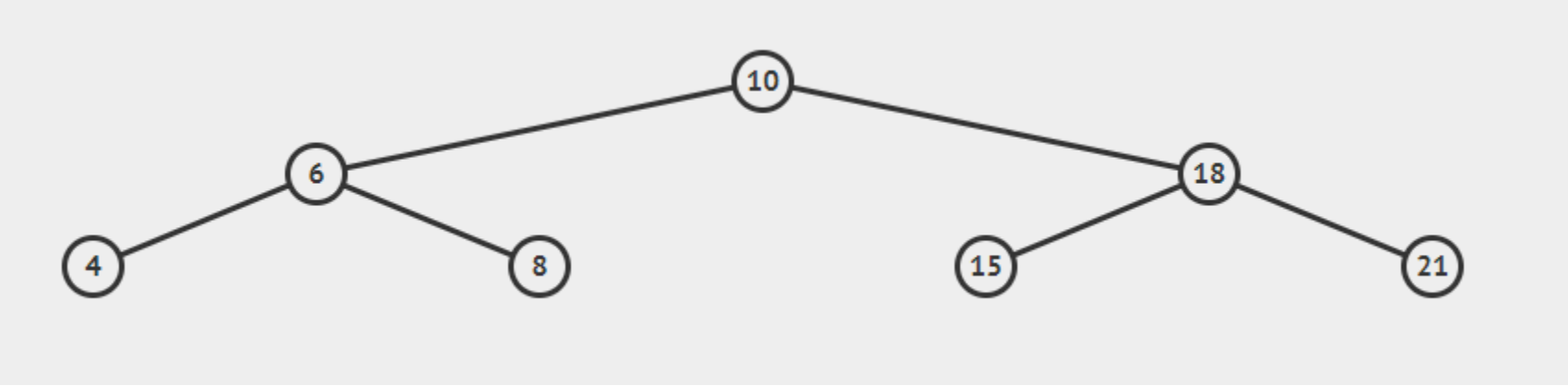
- Draw a Binary Search Tree if the following numbers are inserted in the given order:

10, 6, 4, 8, 18, 21, 15

Binary Search Tree

- Draw a Binary Search Tree if the following numbers are inserted in the given order:

10, 6, 4, 8, 18, 21, 15



why binary search trees?

- Searches that are directed along a single path are **efficient**:
  - a BST with 1 one has height 1
  - a BST with 3 nodes may have height 2
  - a BST with 7 nodes may have height 3
  - a BST with 15 nodes may have height 4
  - a BST with n nodes may have height : $\lceil log_2 n \rceil$

bst contains

- If node is the root of a “balanced” BST, then we can check whether an element is present in about $\lceil log_2 n \rceil$ node accesses.

```
def bst_contains(node: BinaryTree, value: object) ->bool:
    """
    Return whether tree rooted at node contains value.

    Assume node is the root of a Binary Search Tree

    >>> bst_contains(None, 5)
    False
    >>> bst_contains(BinaryTree(7, BinaryTree(5), BinaryTree(9)), 5)
    True
    """
```

```
def bst_contains(node: BinaryTree, value: object) ->bool:
    """
    Return whether tree rooted at node contains value.

    Assume node is the root of a Binary Search Tree

    >>> bst_contains(None, 5)
    False
    >>> bst_contains(BinaryTree(7, BinaryTree(5), BinaryTree(9)), 5)
    True
    """
    if node is None:
        return False
    elif node.value > value:
        return bst_contains(node.left, value)
    elif node.value < value:
        return bst_contains(node.right, value)
    else:
        return True
```

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