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# Binary Search Tree library in Python

December 18, 2010

This article is about a Python library I created to manage binary search trees. I will go over the following:

- Node class
- Insert method
- Lookup method

- Delete method
- Print method
- Comparing 2 trees
- Generator returning the tree elements one by one

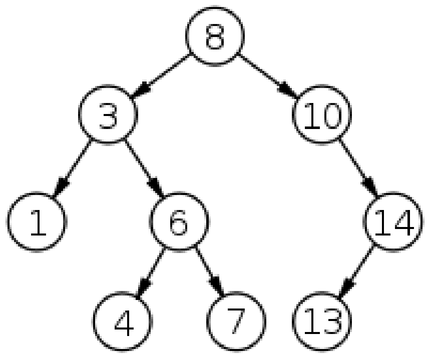
You can checkout the library code on GitHub: git clone https://laurentluce@github.com/laurentluce/python-algorithms.git. This folder contains more libraries but we are just going to focus on the Binary Tree one.

As a reminder, here is a binary search tree definition (Wikipedia).

A binary search tree (BST) or ordered binary tree is a node-based binary tree data structure which has the following properties:

- The left subtree of a node contains only nodes with keys less than the node's key.
- The right subtree of a node contains only nodes with keys greater than the node's key.
- Both the left and right subtrees must also be binary search trees.

Here is an example of a binary search tree:



## Node class

We need to represent a tree node. To do that, we create a new class named Node with 3 attributes:

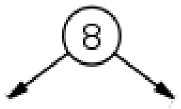
- Left node
- Right node
- Node's data (same as key in the definition above.)

```
class Node:
    """
    Tree node: left and right child + data which can be any object
    """
    def __init__(self, data):
        """
        Node constructor

        @param data node data object
        """
        self.left = None
        self.right = None
        self.data = data
```

Let’s create a tree node containing the integer 8. You can pass any object for the data so it is flexible. When you create a node, both left and right node equal to None.

```
root = Node(8)
```

Note that we just created a tree with a single node.



## Insert method

We need a method to help us populate our tree. This method takes the node’s data as an argument and inserts a new node in the tree.

```
class Node:
    ...
    def insert(self, data):
        """
        Insert new node with data

        @param data node data object to insert
        """
        if data < self.data:
            if self.left is None:
                self.left = Node(data)
            else:
                self.left.insert(data)
        elif data > self.data:
            if self.right is None:
                self.right = Node(data)
            else:
                self.right.insert(data)
```

insert() is called recursively as we are locating the place where to add the new node.

Let’s add 3 nodes to our root node which we created above and let’s look at what the code does.

```
root.insert(3)
root.insert(10)
root.insert(1)
```

This is what happens when we add the second node (3):

- 1- root node’s method insert() is called with data = 3.
- 2- 3 is less than 8 and left child is None so we attach the new node to it.

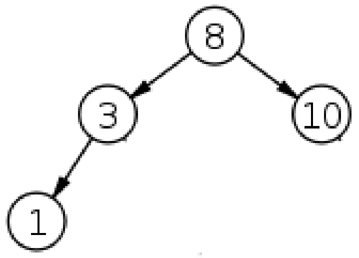
This is what happens when we add the third node (10):

- 1- root node's method insert() is called with data = 10.
- 2- 10 is greater than 8 and right child is None so we attach the new node to it.

This is what happens when we add the fourth node (1):

- 1- root node's method insert() is called with data = 1.
- 2- 1 is less than 8 so the root's left child (3) insert() method is called with data = 1. Note how we call the method on a subtree.
- 3- 1 is less than 3 and left child is None so we attach the new node to it.

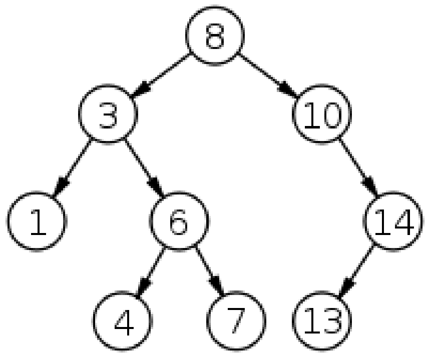
This is how the tree looks like now:



Let's continue and complete our tree so we can move on to the next section which is about looking up nodes in the tree.

```
root.insert(6)
root.insert(4)
root.insert(7)
root.insert(14)
root.insert(13)
```

The complete tree looks like this:



## Lookup method

We need a way to look for a specific node in the tree. We add a new method named lookup which takes a node's data as an argument and returns the node if found or None if not. We also return the node's parent for convenience.

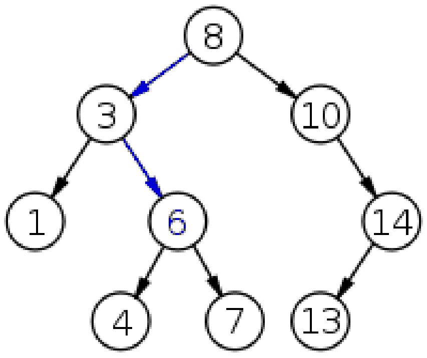
```
class Node:
    ...
    def lookup(self, data, parent=None):
        """
        Lookup node containing data

        @param data node data object to look up
        @param parent node's parent
        @returns node and node's parent if found or None, None
        """
        if data < self.data:
            if self.left is None:
                return None, None
            return self.left.lookup(data, self)
        elif data > self.data:
            if self.right is None:
                return None, None
            return self.right.lookup(data, self)
        else:
            return self, parent
```

Let’s look up the node containing 6.

```
node, parent = root.lookup(6)
```

This is what happens when lookup() is called:

- 1- lookup() is called with data = 6, and default value parent = None.
- 2- data = 6 is less than root’s data which is 8.
- 3- root’s left child lookup() method is called with data = 6, parent = current node. Notice how we call lookup() on a subtree.
- 4- data = 6 is greater than node’s data which is now 3.
- 5- node’s right child lookup() method is called with data = 6 and parent = current node
- 6- node’s data is equal to 6 so we return it and its parent which is node 3.



## Delete method

The method delete() takes the data of the node to remove as an argument.

```
class Node:
    ...
    def delete(self, data):
        """
        Delete node containing data

        @param data node's content to delete
        """
        # get node containing data
        node, parent = self.lookup(data)
        if node is not None:
            children_count = node.children_count()
        ...
```

There are 3 possibilities to handle:

- 1- The node to remove has no child.
- 2- The node to remove has 1 child.
- 3- The node to remove has 2 children.

Let's tackle the first possibility which is the easiest. We look for the node to remove and we set its parent's left or right child to None.

```
def delete(self, data):
    ...
    if children_count == 0:
        # if node has no children, just remove it
        if parent:
            if parent.left is node:
                parent.left = None
            else:
                parent.right = None
        del node
    ...
```

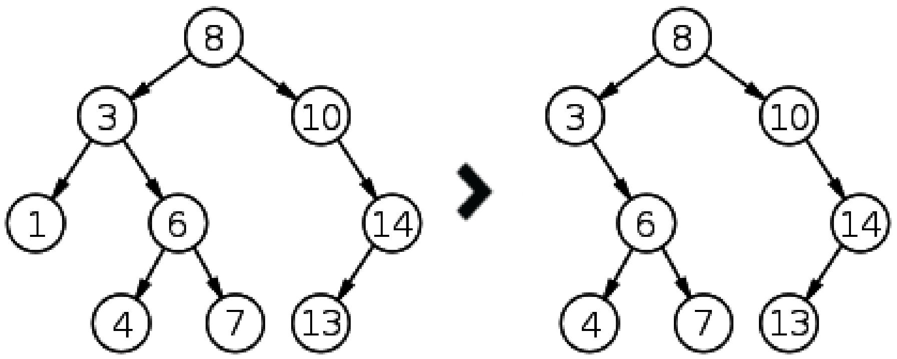
Note: children_count() returns the number of children of a node.

Here is the function children_count:

```
class Node:
    ...
    def children_count(self):
        """
        Returns the number of children

        @returns number of children: 0, 1, 2
        """
        cnt = 0
        if self.left:
            cnt += 1
        if self.right:
            cnt += 1
        return cnt
```

For example, we want to remove node 1. Node 3 left child will be set to None.

```
root.delete(1)
```

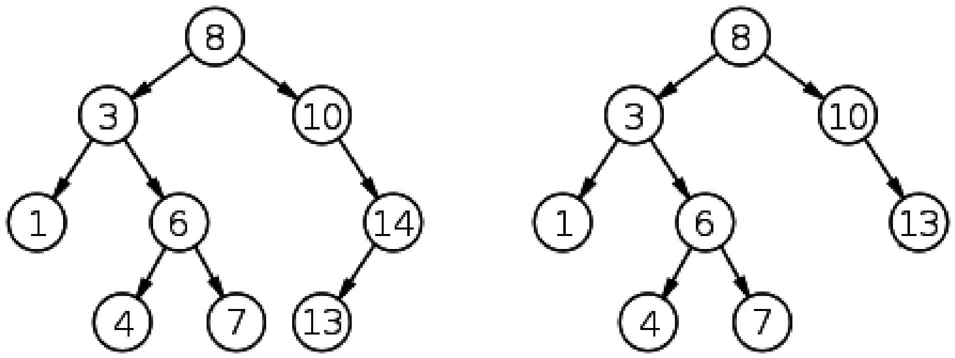


Let’s look at the second possibility which is the node to be removed has 1 child. We replace the node’s data by its left or right child’s data and we set its left or right child to None.

```
def delete(self, data):
    ...
    elif children_count == 1:
        # if node has 1 child
        # replace node by its child
        if node.left:
            n = node.left
        else:
            n = node.right
        if parent:
            if parent.left is node:
                parent.left = n
            else:
                parent.right = n
        del node
    ...
```

For example, we want to remove node 14. Node 14 data will be set to 13 (its left child’s data) and its left child will be set to None.

```
root.delete(14)
```

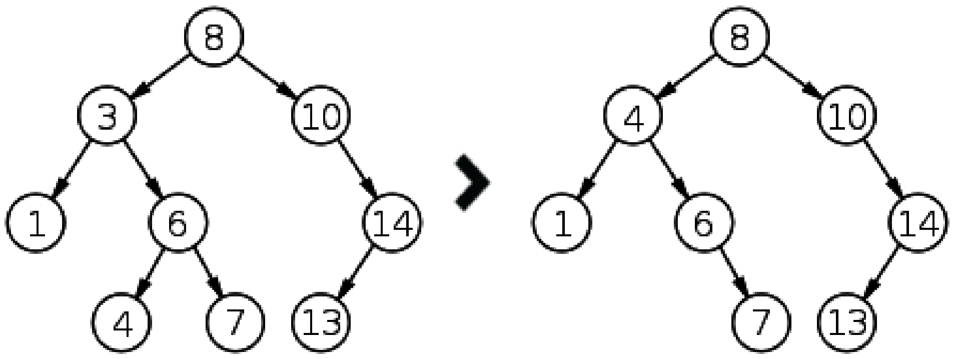


Let’s look at the last possibility which is the node to be removed has 2 children. We replace its data with its successor’s data and we fix the successor’s parent’s child.

```
def delete(self, data):
    ...
    else:
        # if node has 2 children
        # find its successor
        parent = node
        successor = node.right
        while successor.left:
            parent = successor
            successor = successor.left
        # replace node data by its successor data
        node.data = successor.data
        # fix successor's parent's child
        if parent.left == successor:
            parent.left = successor.right
        else:
            parent.right = successor.right
```

For example, we want to remove node 3. We look for its successor by going right then left until we reach a leaf. Its successor is node 4. We replace 3 with 4. Node 4 doesn't have a child so we set node 6 left child to None.

```
root.delete(3)
```



## Print method

We add a method to print the tree inorder. This method has no argument. We use recursion inside print_tree() to walk the tree breath-first. We first traverse the left subtree, then we print the root node then we traverse the right subtree.

```
class Node:
    ...
    def print_tree(self):
        """
        Print tree content inorder
        """
        if self.left:
            self.left.print_tree()
        print self.data,
        if self.right:
            self.right.print_tree()
```

Let's print our tree:

```
root.print_tree()
```

The output will be: 1, 3, 4, 6, 7, 8, 10, 13, 14

## Comparing 2 trees

To compare 2 trees, we add a method which compares each subtree recursively. It returns False when one leaf is not the same in both trees. This includes 1 leaf missing in the other tree or the data is different. We need to pass the root of the tree to compare to as an argument.

```
class Node:
    ...
    def compare_trees(self, node):
        """
        Compare 2 trees

        @param node tree's root node to compare to
        @returns True if the tree passed is identical to this tree
        """
        if node is None:
            return False
        if self.data != node.data:
            return False
        res = True
        if self.left is None:
            if node.left:
                return False
        else:
            res = self.left.compare_trees(node.left)
        if res is False:
            return False
        if self.right is None:
            if node.right:
                return False
        else:
            res = self.right.compare_trees(node.right)
        return res
```

For example, we want to compare tree (3, 8, 10) with tree (3, 8, 11)

```
# root2 is the root of tree 2
root.compare_trees(root2)
```

This is what happens in the code when we call compare_trees().

- 1- The root node compare_trees() method is called with the tree to compare root node.
- 2- The root node has a left child so we call the left child compare_trees() method.
- 3- The left subtree comparison will return True.
- 2- The root node has a right child so we call the right child compare_trees() method.
- 3- The right subtree comparison will return False because the data is different.
- 4- compare_trees() will return False.

## Generator returning the tree elements one by one

It is sometimes useful to create a generator which returns the tree nodes values one by one. It is memory efficient as it doesn't have to build the full list of nodes right away. Each time we call this method, it returns the next node value.

To do that, we use the yield keyword which returns an object and stops right there so the function will continue from there next time the method is called.

We cannot use recursion in this case so we use a stack.

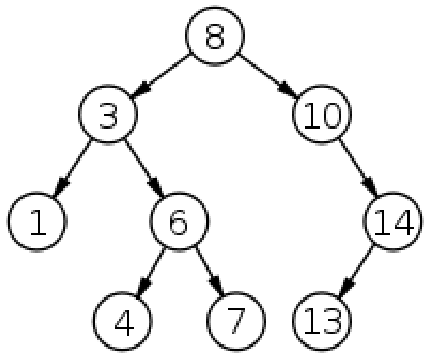
Here is the code:

```
class Node:
    ...
    def tree_data(self):
        """
        Generator to get the tree nodes data
        """
        # we use a stack to traverse the tree in a non-recursive way
        stack = []
        node = self
        while stack or node:
            if node:
                stack.append(node)
                node = node.left
            else: # we are returning so we pop the node and we yield it
                node = stack.pop()
                yield node.data
                node = node.right
```

For example, we want to access the tree nodes using a for loop:

```
for data in root.tree_data():
    print data
```

Let's look at what happens in the code with the same example we have been using:



- 1- The root node tree_data() method is called.
- 2- Node 8 is added to the stack. We go to the left child of 8.
- 3- Node 3 is added to the stack. We go to the left child of 3.
- 4- Node 1 is added to the stack. Node is set to None because there is no left child.
- 5- We pop a node which is Node 1. We yield it (returns 1 and stops here until tree_data() is called again.
- 6- tree_data() is called again because we are using it in a for loop.
- 7- Node is set to None because Node 1 doesn't have a right child.
- 8- We pop a node which is Node 3. We yield it (returns 3 and stops here until tree_data() is called again.
- …

Here you go, I hope you enjoyed this tutorial. Don't hesitate to add comments if you have any feedback.

tags: Python
posted in Uncategorized by Laurent Luce

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## 36 Comments to "Binary Search Tree library in Python"

1. *Ujjwol* wrote:

   Great! Help Thanks.

   Link | December 19th, 2010 at 3:18 am

2. *Nicolas Dumazet* wrote:

   Hello!

   First of all, let me say that this is a great article. You've obviously spent some time on formatting, graphs and code. Kudos.

   But I wonder: is a BinaryTree really different from a Node?
   Think about it. Change the Node constructor signature to __init__(self, data=None), add a getRoot: return self

   Isn't it the same?

It would allow you to define insert/delete/lookup on the BinaryTree object, as a method. Instead of using "root" as a first argument, you'd use "self".
bt.insert(8) instead of bt_insert(root, 8)

Link | December 20th, 2010 at 2:47 am

3. *laurent* wrote:

@Nicolas Dumazet: Thanks for your feedback. I really like your suggestion of just using the class Node as it simplifies the methods arguments. I took the opportunity to update the tutorial with this new design. Let me know what you think of it.

Link | December 20th, 2010 at 6:07 pm

4. *Nicolas Dumazet* wrote:

You're welcome. I'm glad you liked the suggestion! \o/

Double-check the children_count function as well. It could be directly a method of Node instead of acting like a class method: node.children_count() instead of self.children_count(node)

Is which_child required? You can probably go away with an equality comparison. See http://pastebin.com/VRwvN7aX as an illustration.

Cheers!

Link | December 21st, 2010 at 1:46 am

5. *laurent* wrote:

Thanks for your feedback. I updated the code.

Link | December 21st, 2010 at 12:53 pm

6. *LE* wrote:

Interesting, one comment is that you should not compare to None, you should test for identity – i.e. "if x is None:" – comparison is the same as "if not x:" which makes it more clear what you're after (trueness or identity)

Link | December 25th, 2010 at 9:24 am

7. *hamad mohammad* wrote:

i found your explanation by steps is very helpfull for some one like my who can't get it from first time
thank you

and please continue i love your writing style

Link | February 11th, 2011 at 5:25 pm

8. *Laurent Luce* wrote:

@hamad: Thanks.

Link | February 11th, 2011 at 11:55 pm

9. *hamad mohammad* wrote:

if you elaborate little bit in the part of ((removing 2 children|))

Link | March 1st, 2011 at 9:53 am

10. *Cristi Constantin* wrote:

Excellent tutorial !
It would be great if you add a json dump function.

Link | May 16th, 2011 at 5:48 am

11. *Adrian Lienhard* wrote:

Thanks for the post!

Note: there's a bug in the delete function – in the case of one child, only the data is moved up from the successor, but not the successor's children. Hence you'll loose a whole subtree.

Link | June 4th, 2011 at 1:23 pm

12. *Laurent Luce* wrote:

@Adrian: I fixed that. Thanks!

Link | June 11th, 2011 at 2:43 pm

13. *nova* wrote:

the method is located lokoop not work for me? please do some more detailed examples

Link | July 3rd, 2011 at 12:13 am

14. *Laurent Luce* wrote:

@nova: What is not working? Please post more details and some code so I can help you.

Link | July 9th, 2011 at 4:00 pm

15. *game0n* wrote:

```
# fix successor's parent's child
if parent.left == successor:
parent.left = successor.right
else:
parent.right = successor.right
```

for this, i don't understand a check is being made – we were traversing only to the left of parents to find the successor, right? so the code should have only parent.left = successor.right.

If that is not the case, can you please explain with example?
Thanks!

PS: your post has been by far the most helpful resource for me to understand the implementation. Thanks!!

Link | March 15th, 2012 at 2:03 pm

16. *Jaimin* wrote:

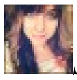
very good article!

Link | March 17th, 2012 at 1:51 pm

17. *David Watson* wrote:

I found this article on binary tree in python very helpful. However, I noticed that the call to tree_data in the example above is missing the parentheses. I forked and sent you a pull request on github. I'm guessing it may confuse some readers. Cheers.

Link | April 10th, 2012 at 5:11 am

18. *Sarah* wrote:

Hi,
I know this is from a year ago, but I am working on a project that requires a binary tree and I found this website so extremely helpful, especially the way you explained everything and made it more visual.

However, with my project my tree has to be letters (for a morse code translation) and I am having trouble with inserting the letters and creating the tree because every website and book I have found they are inserting numbers. Do you have any suggestions on how this could be done? Any help is greatly appreciated.

Link | April 19th, 2012 at 2:41 pm

19. *Ben* wrote:

@nova tree_data is missing the parens in the first example. You'll just need to add those to have it work. i.e.

for data in root.tree_data():
print data

Link | May 11th, 2012 at 8:42 am

20. *Laurent Luce* wrote:

@David Watson: Thanks!

Link | June 1st, 2012 at 6:31 pm

21. *Laurent Luce* wrote:

@Sarah: data in the Node object can be anything. It can be a string like 'A', 'B'… Also, 'A' < 'B' is True in Python.

Link | June 1st, 2012 at 6:40 pm

22. *Laurent Luce* wrote:

@gameOn: In the example where we remove Node 3. If Node 6 has no children then parent.right will be equal to successor.

Link | June 1st, 2012 at 6:58 pm

23. *Manoj* wrote:

beautiful programming, I read only up till init, insert,find. while I read the c implementations on data structures by Weiss and was looking for translating it to python I had difficulties so I came over to learn from yours 🙂

Link | July 4th, 2012 at 3:37 am

24. *Manoj* wrote:

u can never delete root right? and so does a node deleted bubbled down by its successors until a leaf or 1 child is reached which is deleted easily???

Link | July 9th, 2012 at 6:51 am

25. *Christo* wrote:

Great article. Extremely well written! Thanks for putting it together it has helped me a lot.

Link | July 16th, 2012 at 12:09 pm

26. *snehaa* wrote:

excellent work… helps alot to understand the concepts of trees very clearly and deeply.. thanks alot…

Link | April 11th, 2013 at 9:54 am

27. *Raveesh* wrote:

Awesome! Loved your detailed explanation of each and every step! 😃

Link | August 16th, 2013 at 5:45 pm

28. *Uthpala* wrote:

very well written,nice and detailed article.Thank you very much.

Link | October 7th, 2013 at 9:27 pm

29. *Chris* wrote:

Thanks for sharing, Laurent. I ended up using some of your code in my CS 101 class today: http://w3.cs.jmu.edu/mayfiecs/cs101/wk-10/Lab10-BinaryTree.html

Link | November 1st, 2013 at 12:42 pm

30. *Matt L* wrote:

Great article – a small suggestion is in the insert method to change "else:" to "elif data > self.data:" to throw out duplicates – it will then match the definition of binary search tree you've provided (and your lookup and delete methods will not have to handle multiple match cases).

Link | January 1st, 2014 at 5:26 pm

31. *Dan Stromberg* wrote:

I've taken this page and packaged it up as a Python 2.x and 3.x Dictionary-like binary tree module. It's at http://stromberg.dnsalias.org/~strombrg/linked-list/

Link | February 10th, 2014 at 6:22 pm

32. *Liangyue Li* wrote:

For comparing two binary trees,
res = self.left.compare_trees(node.left)
if the two left subtrees are not the same, res = false, but will be overwritten by res = self.right.compare_trees(node.right)
, which will return true if the two right subtrees are the same.

Link | March 21st, 2014 at 10:20 pm

33. *Laurent Luce* wrote:

@Liangyue Li: Thanks! I updated the method to return False if self.left.compare_trees returns False.

Link | May 25th, 2014 at 8:48 pm

34. *Laurent Luce* wrote:

@Matt L: Great suggestion!

Link | May 25th, 2014 at 9:17 pm

35. *Titus* wrote:

Hey, great article!

One small note, in the children_count method the lines 9 and 10 are not needed.

09
if node is None:
10
return None

Cheers

Link | July 12th, 2014 at 10:57 am

36. *Laurent Luce* wrote:

@Titus: Those lines were removed on GitHub but not on the post. Thanks!

Link | July 23rd, 2014 at 9:33 pm

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