CSC148 winter 2014

linked structures

week 8

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Outline

LinkedList again

linked list node class with wrapper class

binary search trees

regular expressions

Start by designing a class hierarchy. What information is needed for each type of regular expression tree? What information is specialized? What's general?
Look at Week 6's **Tree** class in tree.py for ideas.

Alternative initializer for LinkedList class

Included in linked_list.py

```
class AltLinkedList:
  def __init__(self,*args):
    if len(args) == 0:
      self.empty = True
    elif len(args) == 1:
      self.empty = False
      self.head = args[0]
      self.rest = AltLinkedList()
    elif len(args) == 2:
      self.empty = False
      self.head = args[0]
      assert isinstance(args[1], AltLinkedList)
      self.rest = args[1]
    else: # len(args) > 2:
      raise Exception("AltLinkedList initializer takes ''
                      "between 0 and 2 arguments.")
```

design choices

AltLinkedList initialization reveals design choices

- **AltLinkedList()** creates an empty list
- **AltLinkedList(obj)** creates a 1-element list with **head** = obj
- **AltLinkedList(obj,otherlist)** creates a linked list with **head** = obj and **rest** = otherlist.
- it's possible for **head** to refer to None — why might you want this?
- **rest** refers to another **AltLinkedList** with the same structure

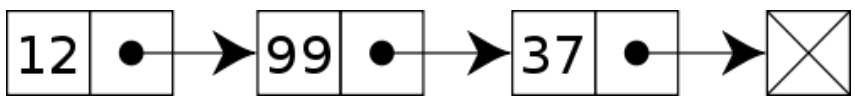
This isn't the only design for a linked list, for example How to think like a computer scientist shows the "wrapper" approach.

implement **prepend(head)**

main goals are to preserve the list identity (same id) and preserve the previous contents

- start the rest of the list with the current attributes (shallow **copy** them)
- change the current head to the one passed in
- change the current rest to the copy!

Try drawing the result of **prepend(5)**



implement prepend(head)

```
def prepend(self: 'LinkedList', head: object) -> None:
  old_head = copy(self)
  self.rest = old_head
  self.head = head
  self.empty = False
```

what's wrong with this implementation of **prepend(head)**?

```
def prepend(self: 'LinkedList', head: object) -> None:
  new_head = LinkedList(head, self)
  self = new_head
  self.empty = False
```

what about this **prepend(head)**?

It's usage is different; if you want to add 9 to LinkedList x you do:
x = x.prepend(9)

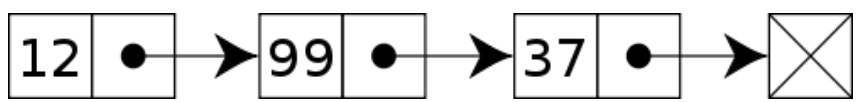
```
def prepend(self: 'LinkedList', head: object) -> 'LinkedList':
  new_head = LinkedList(head, self)
  return new_head
```

linked lists, two concepts

There are two useful, but different, ways of thinking of linked list structures

1. as lists made up of an item (value) and the remaining list (rest)

2. as objects (nodes) with a value and a reference to other similar objects



a node class

```
class LListNode:
    """Node to be used in linked list"""

    def __init__(self: 'LListNode', value: object,
                 nxt: 'LListNode' =None) -> None:
        """Create a new LListNode containing value
        referring to next node nxt

        nxt --- None if and only if we are on the last node
        value --- always a Python object, there are no empty nodes
        """
        self.value, self.nxt = value, nxt
```

a wrapper class for list

The list class keeps track of information about the entire list — such as its front.

```
class LinkedList:
    """Collection of LListNodes"""

    def __init__(self: 'LinkedList') -> None:
        """Create an empty LinkedList"""
        self.front = None
        self.size = 0
```

insertion

```
def insert(self: 'LinkedList', value: object) -> None:
    """Insert LListNode with value at front of self

    >>> lnk = LinkedList()
    >>> lnk.insert(0)
    >>> lnk.insert(1)
    >>> lnk.insert(2)
    >>> str(lnk.front)
    '2 -> 1 -> 0 -> None'
    >>> lnk.size
    3
    """
```

deletion

```
"""Delete front LListNode from self

self must not be None

>>> lnk = LinkedList()
>>> lnk.insert(0)
>>> lnk.insert(1)
>>> lnk.insert(2)
>>> lnk.delete_front()
>>> str(lnk.front)
'1 -> 0 -> None'
>>> lnk.size
2
"""
```

reversing

```
def reverse_links(ln: LListNode) -> LListNode:
    """Reverse the (virtual) linked list that starts at ln, by
    modifying the next attributes of all the LListNodes reachable
    from ln, and return the front node of the (virtual) reversed
    linked list.

    ln is not None

    >>> ln = LListNode(0)
    >>> ln1 = LListNode(1, ln)
    >>> ln2 = LListNode(2, ln1)
    >>> ln3 = LListNode(3, ln2)
    >>> lnr = reverse_links(ln3)
    >>> str(lnr)
    '0 -> 1 -> 2 -> 3 -> None'
    """
```

wrapper/node binary tree

instead of single tree class, separate node and bst classes:

```
class BTNode:
    """Binary Tree node."""

    def __init__(self: 'BTNode', data: object,
                 left: 'BTNode'=None,
                 right: 'BTNode'=None) -> None:
        """Create BT node with data, children left and right."""
        self.data, self.left, self.right = data, left, right
```

string representation

Python _str_ methods are more informal than _repr_ methods. I had to start with a helper function (why?)

```
def _str(b: BTNode, i: str) -> str:
    """Return a string representing self inorder
    indent by i"""
    return ((_str(b.right, i + '    ') if b.right else '') +
            i + str(b.data) + '\n' +
            (_str(b.left, i + '    ') if b.left else ''))
```

...now the __str__ method is easy

```
def __str__(self: 'BTNode') -> str:
    """Return a string representing self inorder"""
    return _str(self, '')
```

binary search tree

Add a condition: data in left subtree is less than that in the root, which in turn is less than that in right subtree. Now search is more efficient...

```
class BST:
    """Binary search tree."""

    def __init__(self: 'BST', root: BTNode=None) -> None:
        """Create BST with BTNode root."""
        self._root = root
```

insert must obey condition

Careful reading of the example show that we expect **insert** to ensure this is a binary **search** tree:

```
    def insert(self: 'BST', data: object) -> None:
        """Insert data, if necessary, into this tree.

        >>> b = BST()
        >>> b.insert(8)
        >>> b.insert(4)
        >>> b.insert(2)
        >>> b.insert(6)
        >>> b.insert(12)
        >>> b.insert(14)
        >>> b.insert(10)
        >>> b
        BST(BTNode(8, BTNode(4, BTNode(2, None, None), BTNode(6, None,
BTNode(12, BTNode(10, None, None), BTNode(14, None, None))))
    """
        self._root = _insert(self._root, data)
```

helper function...

the wrapper/node design means that the recursive structures are **BTNodes** rather than **BST**, so write a module-level function as a helper:

```
def _insert(node: BTNode, data: object) -> BTNode:
    """Insert data starting at node, and return root."""
    return_node = node
    if not node:
        return_node = BTNode(data)
    elif data < node.data:
        node.left = _insert(node.left, data)
    elif data > node.data:
        node.right = _insert(node.right, data)
    else:  # nothing to do
        pass
    return return_node
```

quickly search in a BST

```
def _find(node: BTNode, data: object):
    """Return the node containing data, or else None."""
    if node is None or node.data == data:
        return node

    if data < node.data:
     return _find(node.left, data)
    else:
     return _find(node.right, data)
```