Homework 5 Solutions

hw05.zip (hw05.zip)

Solution Files

You can find the solutions in hw05.py (hw05.py).

Required Questions

OOP

Q1: Vending Machine

Create a class called `VendingMachine` that represents a vending machine for some product. A `VendingMachine` object returns strings describing its interactions.
Fill in the `VendingMachine` class, adding attributes and methods as appropriate, such that its behavior matches the following doctests:

```
class VendingMachine:
    """A vending machine that vends some product for some price.

    >>> v = VendingMachine('candy', 10)
    >>> v.vend()
    'Machine is out of stock.'
    >>> v.add_funds(15)
    'Machine is out of stock. Here is your $15.'
    >>> v.restock(2)
    'Current candy stock: 2'
    >>> v.vend()
    'You must add $10 more funds.'
    >>> v.add_funds(7)
    'Current balance: $7'
    >>> v.vend()
    'You must add $3 more funds.'
    >>> v.add_funds(5)
    'Current balance: $12'
    >>> v.vend()
    'Here is your candy and $2 change.'
    >>> v.add_funds(10)
    'Current balance: $10'
    >>> v.vend()
    'Here is your candy.'
    >>> v.add_funds(15)
    'Machine is out of stock. Here is your $15.'

    >>> w = VendingMachine('soda', 2)
    >>> w.restock(3)
    'Current soda stock: 3'
    >>> w.restock(3)
    'Current soda stock: 6'
    >>> w.add_funds(2)
    'Current balance: $2'
    >>> w.vend()
    'Here is your soda.'
    """
    def __init__(self, product, price):
        self.product = product
        self.price = price
        self.stock = 0
        self.balance = 0

    def restock(self, n):
        self.stock += n
```

```
        return 'Current {0} stock: {1}'.format(self.product, self.stock)

    def add_funds(self, n):
        if self.stock == 0:
            return 'Machine is out of stock. Here is your ${0}.'.format(n)
        self.balance += n
        return 'Current balance: ${0}'.format(self.balance)

    def vend(self):
        if self.stock == 0:
            return 'Machine is out of stock.'
        difference = self.price - self.balance
        if difference > 0:
            return 'You must add ${0} more funds.'.format(difference)
        message = 'Here is your {0}'.format(self.product)
        if difference != 0:
            message += ' and ${0} change'.format(-difference)
        self.balance = 0
        self.stock -= 1
        return message + '.'
```

> You may find Python string formatting syntax (https://docs.python.org/2/library/stdtypes.html#str.format) useful. A quick example:

```
>>> ten, twenty, thirty = 10, 'twenty', [30]
>>> '{0} plus {1} is {2}'.format(ten, twenty, thirty)
'10 plus twenty is [30]'
```

Use Ok to test your code:

```
python3 ok -q VendingMachine
```

Reading through the doctests, it should be clear which functions we should add to ensure that the vending machine class behaves correctly.

`__init__`

- This can be difficult to fill out at first. Both `product` and `price` seem pretty obvious to keep around, but `stock` and `balance` are quantities that are needed only after attempting other functions.

`restock`

- Even though `v.restock(2)` takes only one argument in the doctest, remember that `self` is bound to the object the `restock` method is invoked on. Therefore, this function has two parameters.
- While implementing this function, you will probably realize that you would like to keep track of the stock somewhere. While it might be possible to set the stock in this function as an instance attribute, it would lose whatever the old stock was. Therefore, the natural solution is to initialize stock in the constructor, and then update it in `restock`.

`add_funds`

- This behaves very similarly to `restock`. See comments above.
- Also yes, this is quite the expensive vending machine.

`vend`

- The trickiest thing here is to make sure we handle all the cases. You may find it helpful when implementing a problem like this to keep track of all the errors we run into in the doctest.
  1. No stock
  2. Not enough balance
  3. Leftover balance after purchase (return change to customer)
  4. No leftover balance after purchase
- We use some string concatenation at the end when handling case 3 and 4 to try and reduce the amount of code. This isn't necessary for correctness -- it's ok to have something like:

  ```
  if difference != 0:
      return ...
  else:
      return ...
  ```

  Of course, that would require decrementing the balance and stock beforehand.

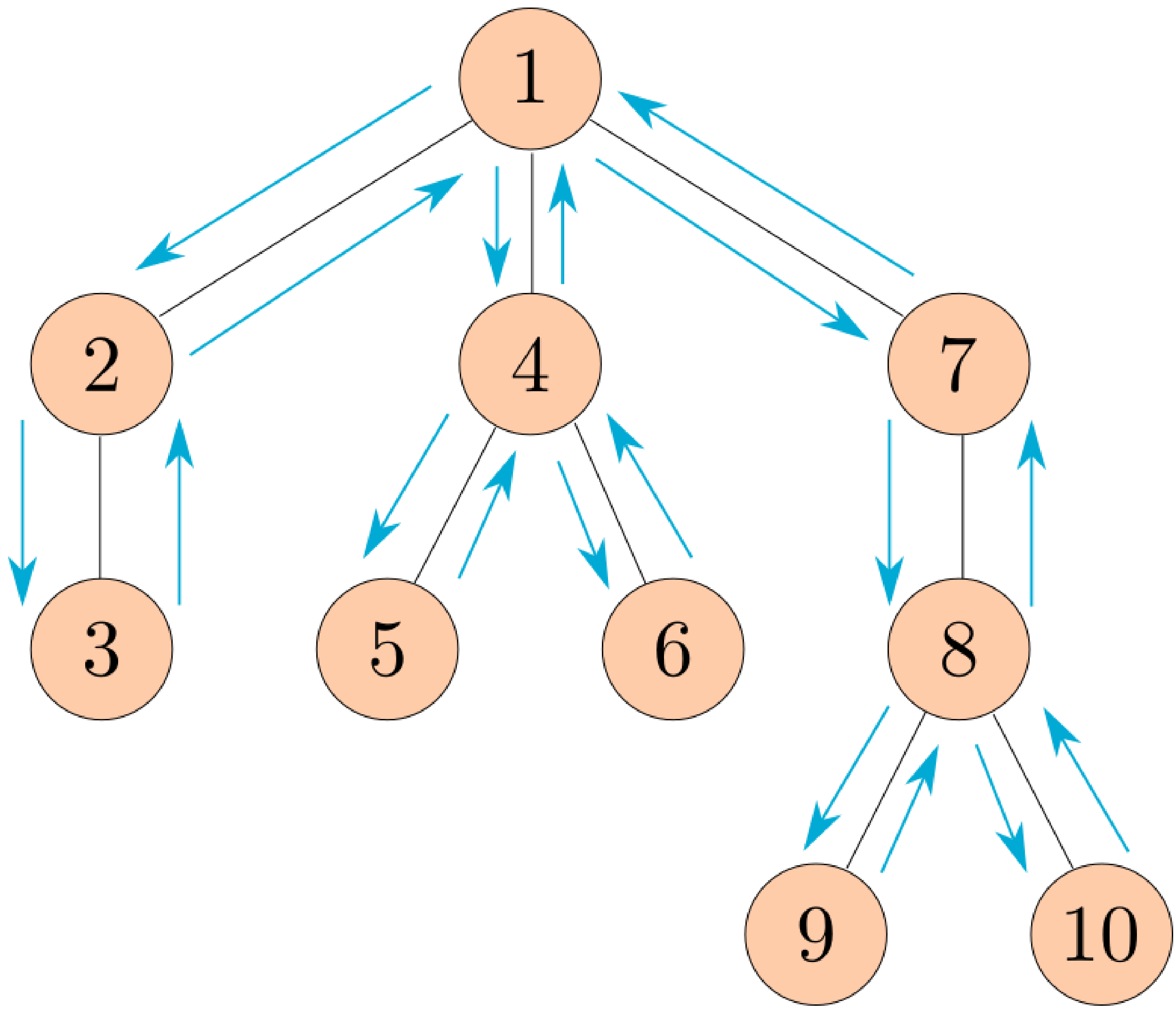
Video walkthrough: https://youtu.be/7A8WtnX89z4 (https://youtu.be/7A8WtnX89z4)

Trees

Q2: Preorder

Define the function `preorder`, which takes in a tree as an argument and returns a list of all the entries in the tree in the order that `print_tree` would print them.

The following diagram shows the order that the nodes would get printed, with the arrows representing function calls.



Note: This ordering of the nodes in a tree is called a preorder traversal.

```
def preorder(t):
    """Return a list of the entries in this tree in the order that they
    would be visited by a preorder traversal (see problem description).

    >>> numbers = Tree(1, [Tree(2), Tree(3, [Tree(4), Tree(5)]), Tree(6, [Tree(7
    >>> preorder(numbers)
    [1, 2, 3, 4, 5, 6, 7]
    >>> preorder(Tree(2, [Tree(4, [Tree(6)])]))
    [2, 4, 6]
    """
    if t.branches == []:
        return [t.label]
    flattened_children = []
    for child in t.branches:
        flattened_children += preorder(child)
    return [t.label] + flattened_children

# Alternate solution
from functools import reduce

def preorder_alt(t):
    return reduce(add, [preorder(child) for child in t.branches], [t.label])
```

Use Ok to test your code:

```
python3 ok -q preorder
```

Linked Lists

Q3: Store Digits

Write a function `store_digits` that takes in an integer `n` and returns a linked list where each element of the list is a digit of `n`.

```
def store_digits(n):
    """Stores the digits of a positive number n in a linked list.

    >>> s = store_digits(1)
    >>> s
    Link(1)
    >>> store_digits(2345)
    Link(2, Link(3, Link(4, Link(5))))
    >>> store_digits(876)
    Link(8, Link(7, Link(6)))
    """
    result = Link.empty
    while n > 0:
        result = Link(n % 10, result)
        n //= 10
    return result
```

Use Ok to test your code:

```
python3 ok -q store_digits
```

Generators/Trees

Q4: Generate Paths

Define a generator function `generate_paths` which takes in a Tree `t`, a value `value`, and returns a generator object which yields each path from the root of `t` to a node that has label `value`.

`t` is implemented with a class, not as the function-based ADT.

Each path should be represented as a list of the labels along that path in the tree. You may yield the paths in any order.

We have provided a (partial) skeleton for you. You do not need to use this skeleton, but if your implementation diverges significantly from it, you might want to think about how you can get it to fit the skeleton.

```python
def generate_paths(t, value):
    """Yields all possible paths from the root of t to a node with the label val
    as a list.

    >>> t1 = Tree(1, [Tree(2, [Tree(3), Tree(4, [Tree(6)]), Tree(5)]), Tree(5)])
    >>> print(t1)
    1
      2
        3
        4
          6
        5
      5
    >>> next(generate_paths(t1, 6))
    [1, 2, 4, 6]
    >>> path_to_5 = generate_paths(t1, 5)
    >>> sorted(list(path_to_5))
    [[1, 2, 5], [1, 5]]

    >>> t2 = Tree(0, [Tree(2, [t1])])
    >>> print(t2)
    0
      2
        1
          2
            3
            4
              6
            5
          5
    >>> path_to_2 = generate_paths(t2, 2)
    >>> sorted(list(path_to_2))
    [[0, 2], [0, 2, 1, 2]]
    """

    if t.label == value:
        yield [value]

    for b in t.branches:
        for path in generate_paths(b, value):

                yield [t.label] + path
```

> Hint: If you're having trouble getting started, think about how you'd approach this problem if it wasn't a generator function. What would your recursive calls be? With a generator function, what happens if you make a "recurisve call" within its body?

Use Ok to test your code:

```
python3 ok -q generate_paths
```

If our current label is equal to `value`, we've found a path from the root to a node containing `value` containing only our current label, so we should yield that. From there, we'll see if there are any paths starting from one of our branches that ends at a node containing `value`. If we find these "partial paths" we can simply add our current label to the beinning of a path to obtain a path starting from the root.

In order to do this, we'll create a generator for each of the branches which yields these "partial paths". By calling `generate_paths` on each of the branches, we'll create exactly this generator! Then, since a generator is also an iterable, we can iterate over the paths in this generator and yield the result of concatenating it with our current label.

Submit

Make sure to submit this assignment by running:

```
python3 ok --submit
```

Optional Questions

> These are recommended as review for the exam!

Q5: Is BST

Write a function `is_bst`, which takes a Tree `t` and returns `True` if, and only if, `t` is a valid binary search tree, which means that:

- Each node has at most two children (a leaf is automatically a valid binary search tree)
- The children are valid binary search trees

- For every node, the entries in that node's left child are less than or equal to the label of the node
- For every node, the entries in that node's right child are greater than the label of the node

An example of a BST is:

bst

Note that, if a node has only one child, that child could be considered either the left or right child. You should take this into consideration.

Hint: It may be helpful to write helper functions `bst_min` and `bst_max` that return the minimum and maximum, respectively, of a Tree if it is a valid binary search tree.

```
def is_bst(t):
    """Returns True if the Tree t has the structure of a valid BST.

    >>> t1 = Tree(6, [Tree(2, [Tree(1), Tree(4)]), Tree(7, [Tree(7), Tree(8)]
    >>> is_bst(t1)
    True
    >>> t2 = Tree(8, [Tree(2, [Tree(9), Tree(1)]), Tree(3, [Tree(6)]), Tree(5
    >>> is_bst(t2)
    False
    >>> t3 = Tree(6, [Tree(2, [Tree(4), Tree(1)]), Tree(7, [Tree(7), Tree(8)]
    >>> is_bst(t3)
    False
    >>> t4 = Tree(1, [Tree(2, [Tree(3, [Tree(4)])])])
    >>> is_bst(t4)
    True
    >>> t5 = Tree(1, [Tree(0, [Tree(-1, [Tree(-2)])])])
    >>> is_bst(t5)
    True
    >>> t6 = Tree(1, [Tree(4, [Tree(2, [Tree(3)])])])
    >>> is_bst(t6)
    True
    >>> t7 = Tree(2, [Tree(1, [Tree(5)]), Tree(4)])
    >>> is_bst(t7)
    False
    """
    def bst_min(t):
        """Returns the min of t, if t has the structure of a valid BST."""
        if t.is_leaf():
            return t.label
        return min(t.label, bst_min(t.branches[0]))

    def bst_max(t):
        """Returns the max of t, if t has the structure of a valid BST."""
        if t.is_leaf():
            return t.label
        return max(t.label, bst_max(t.branches[-1]))

    if t.is_leaf():
        return True
    if len(t.branches) == 1:
        c = t.branches[0]
        return is_bst(c) and (bst_max(c) <= t.label or bst_min(c) > t.label)
    elif len(t.branches) == 2:
        c1, c2 = t.branches
```

```
        return valid_branches and bst_max(c1) <= t.label and bst_min(c2) > t.lal
    else:
        return False
```

Use Ok to test your code:

```
python3 ok -q is_bst
```

Q6: Mint

Complete the `Mint` and `Coin` classes so that the coins created by a mint have the correct year and worth.

- Each `Mint` instance has a `year` stamp. The `update` method sets the `year` stamp to the `current_year` class attribute of the `Mint` class.
- The `create` method takes a subclass of `Coin` and returns an instance of that class stamped with the `mint` 's year (which may be different from `Mint.current_year` if it has not been updated.)
- A `Coin` 's `worth` method returns the `cents` value of the coin plus one extra cent for each year of age beyond 50. A coin's age can be determined by subtracting the coin's year from the `current_year` class attribute of the `Mint` class.

```python
class Mint:
    """A mint creates coins by stamping on years.

    The update method sets the mint's stamp to Mint.current_year.

    >>> mint = Mint()
    >>> mint.year
    2020
    >>> dime = mint.create(Dime)
    >>> dime.year
    2020
    >>> Mint.current_year = 2100  # Time passes
    >>> nickel = mint.create(Nickel)
    >>> nickel.year     # The mint has not updated its stamp yet
    2020
    >>> nickel.worth()  # 5 cents + (80 - 50 years)
    35
    >>> mint.update()   # The mint's year is updated to 2100
    >>> Mint.current_year = 2175     # More time passes
    >>> mint.create(Dime).worth()    # 10 cents + (75 - 50 years)
    35
    >>> Mint().create(Dime).worth()  # A new mint has the current year
    10
    >>> dime.worth()     # 10 cents + (155 - 50 years)
    115
    >>> Dime.cents = 20  # Upgrade all dimes!
    >>> dime.worth()     # 20 cents + (155 - 50 years)
    125

    >>> m = Mint()
    >>> n = m.create(Nickel)
    >>> n.worth()
    5
    >>> n.year = 2020
    >>> n.worth()
    113
    """
    current_year = 2020

    def __init__(self):
        self.update()

    def create(self, kind):
        return kind(self.year)
```

```
    def update(self):
        self.year = Mint.current_year

class Coin:
    def __init__(self, year):
        self.year = year

    def worth(self):
        return self.cents + max(0, Mint.current_year - self.year - 50)

class Nickel(Coin):
    cents = 5

class Dime(Coin):
    cents = 10
```

Use Ok to test your code:

```
python3 ok -q Mint
```

Q7: Remove All

Implement a function `remove_all` that takes a `Link`, and a `value`, and remove any linked list node containing that value. You can assume the list already has at least one node containing `value` and the first element is never removed. Notice that you are not returning anything, so you should mutate the list.

```python
def remove_all(link , value):
    """Remove all the nodes containing value in link. Assume that the
    first element is never removed.

    >>> l1 = Link(0, Link(2, Link(2, Link(3, Link(1, Link(2, Link(3)))))))
    >>> print(l1)
    <0 2 2 3 1 2 3>
    >>> remove_all(l1, 2)
    >>> print(l1)
    <0 3 1 3>
    >>> remove_all(l1, 3)
    >>> print(l1)
    <0 1>
    >>> remove_all(l1, 3)
    >>> print(l1)
    <0 1>
    """
    if link is Link.empty or link.rest is Link.empty:
        return
    if link.rest.first == value:
        link.rest = link.rest.rest
        remove_all(link, value)
    else:
        remove_all(link.rest, value)

    # alternate solution
    if link is not Link.empty and link.rest is not Link.empty:
        remove_all(link.rest, value)
        if link.rest.first == value:
            link.rest = link.rest.rest

    # Video Walkthrough: https://youtu.be/hdO9Ry8d5FU?t=39m33s
```

Use Ok to test your code:

```
python3 ok -q remove_all
```

Q8: Deep Map

Implement `deep_map`, which takes a function `f` and a `link`. It returns a *new* linked list with the same structure as `link`, but with `f` applied to any element within `link` or any `Link` instance contained in `link`.

The `deep_map` function should recursively apply `fn` to each of that `Link`'s elements rather than to that `Link` itself.

Hint: You may find the built-in `isinstance` function useful. You can also use the `type(link) == Link` to check whether an object is a linked list (like you did in homework 3 question 1).

```
def deep_map(f, link):
    """Return a Link with the same structure as link but with fn mapped over
    its elements. If an element is an instance of a linked list, recursively
    apply f inside that linked list as well.

    >>> s = Link(1, Link(Link(2, Link(3)), Link(4)))
    >>> print(deep_map(lambda x: x * x, s))
    <1 <4 9> 16>
    >>> print(s) # unchanged
    <1 <2 3> 4>
    >>> print(deep_map(lambda x: 2 * x, Link(s, Link(Link(Link(5))))))
    <<2 <4 6> 8> <<10>>>
    """
    if link is Link.empty:
        return link
    if isinstance(link.first, Link):
        first = deep_map(f, link.first)
    else:
        first = f(link.first)
    return Link(first, deep_map(f, link.rest))
```

Use Ok to test your code:

```
python3 ok -q deep_map
```