## CS 61A Fall 2014

# Structure and Interpretation of Computer Programs

MIDTERM 2 SOLUTIONS

#### INSTRUCTIONS

- You have 2 hours to complete the exam.
- The exam is closed book, closed notes, closed computer, closed calculator, except one hand-written  $8.5" \times 11"$  crib sheet of your own creation and the 2 official 61A midterm study guides attached to the back of this exam.
- Mark your answers ON THE EXAM ITSELF. If you are not sure of your answer you may wish to provide a brief explanation.

Last name	
First name	
SID	
Login	
TA & section time	
Name of the person to your left	
Name of the person to your right	
All the work on this exam is my own. (please sign)	

For staff use only

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Q. 1	Q. 2	Q. 3	Q. 4	Q. 5	Total
/12	/14	/8	/8	/8	/50

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#### 1. (12 points) Class Hierarchy

For each row below, write the output displayed by the interactive Python interpreter when the expression is evaluated. Expressions are evaluated in order, and expressions may affect later expressions.

Whenever the interpreter would report an error, write ERROR. You *should* include any lines displayed before an error. *Reminder*: The interactive interpreter displays the **repr** string of the value of a successfully evaluated expression, unless it is **None**. Assume that you have started Python 3 and executed the following:

```
class Worker:
   greeting = 'Sir'
    def __init__(self):
        self.elf = Worker
    def work(self):
        return self.greeting + ', I work'
    def __repr__(self):
        return Bourgeoisie.greeting
class Bourgeoisie(Worker):
    greeting = 'Peon'
    def work(self):
        print(Worker.work(self))
        return 'My job is to gather wealth'
class Proletariat(Worker):
    greeting = 'Comrade'
    def work(self, other):
        other.greeting = self.greeting + ' ' + other.greeting
        other.work() # for revolution
        return other
jack = Worker()
john = Bourgeoisie()
jack.greeting = 'Maam'
```

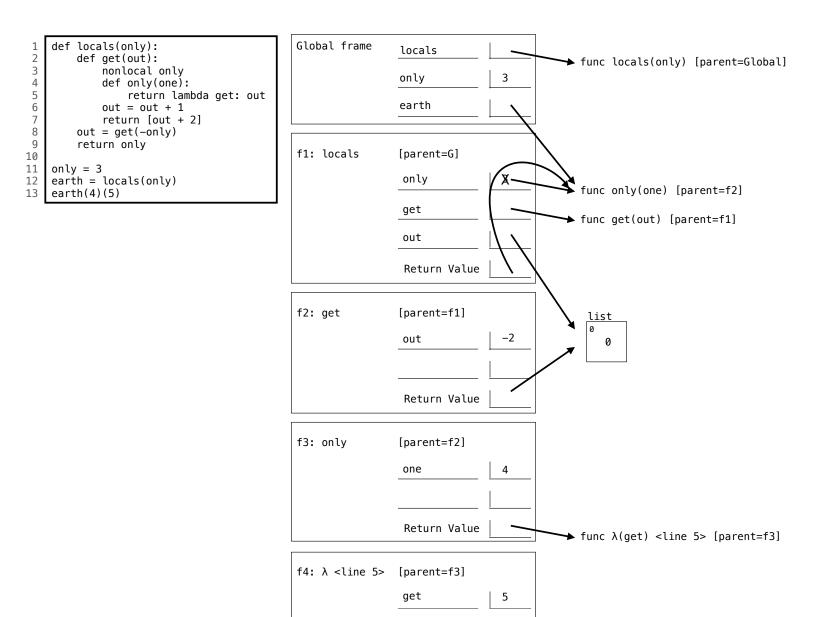
Expression	Interactive Output
5*5	25
1/0	Error
Worker().work()	'Sir, I work'
jack	Peon
jack.work()	'Maam, I work'

Expression	Interactive Output
john.work()[10:]	Peon, I work 'to gather wealth'
Proletariat().work(john)	Comrade Peon, I work Peon
<pre>john.elf.work(john)</pre>	'Comrade Peon, I work'

#### 2. (14 points) Space

- (a) (8 pt) Fill in the environment diagram that results from executing the code below until the entire program is finished, an error occurs, or all frames are filled. You may not need to use all of the spaces or frames.

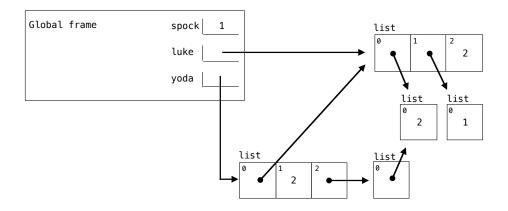
  A complete answer will:
  - Add all missing names and parent annotations to all local frames.
  - Add all missing values created during execution.
  - Show the return value for each local frame.



-2

Return Value

(b) (6 pt) Fill in the blanks with the shortest possible expressions that complete the code in a way that results in the environment diagram shown. You can use only brackets, commas, colons, and the names luke, spock, and yoda. You \*cannot\* use integer literals, such as 0, in your answer! You also cannot call any built-in functions or invoke any methods by name.



#### 3. (8 points) This One Goes to Eleven

(a) (4 pt) Fill in the blanks of the implementation of sixty\_ones below, a function that takes a Link instance representing a sequence of integers and returns the number of times that 6 and 1 appear consecutively.

```
def sixty_ones(s):
        """Return the number of times that 1 follows 6 in linked list s.
        >>> once = Link(4, Link(6, Link(1, Link(6, Link(0, Link(1))))))
        >>> twice = Link(1, Link(6, Link(1, once)))
        >>> thrice = Link(6, twice)
        >>> apply_to_all(sixty_ones, [Link.empty, once, twice, thrice])
        [0, 1, 2, 3]
        11 11 11
        if s is Link.empty or s.rest is Link.empty:
            return 0
        elif s.first == 6 and s.rest.first == 1:
            return 1 + sixty_ones(s.rest.rest)
        else:
            return sixty_ones(s.rest)
(b) (4 pt) Fill in the blanks of the implementation of no_eleven below, a function that returns a list of all
   distinct length-n lists of ones and sixes in which 1 and 1 do not appear consecutively.
   def no_eleven(n):
        """Return a list of lists of 1's and 6's that do not contain 1 after 1.
        >>> no_eleven(2)
        [[6, 6], [6, 1], [1, 6]]
        >>> no_eleven(3)
        [[6, 6, 6], [6, 6, 1], [6, 1, 6], [1, 6, 6], [1, 6, 1]]
        >>> no_eleven(4)[:4] # first half
        [[6, 6, 6, 6], [6, 6, 6, 1], [6, 6, 1, 6], [6, 1, 6, 6]]
        >>> no_eleven(4)[4:] # second half
        [[6, 1, 6, 1], [1, 6, 6, 6], [1, 6, 6, 1], [1, 6, 1, 6]]
        if n == 0:
            return [[]]
        elif n == 1:
            return [[6], [1]]
        else:
            a, b = no\_eleven(n-1), no\_eleven(n-2)
            return [[6] + s for s in a] + [[1, 6] + s for s in b]
```

#### 4. (8 points) Tree Time

(a) (4 pt) A GrootTree g is a binary tree that has an attribute parent. Its parent is the GrootTree in which g is a branch. If a GrootTree instance is not a branch of any other GrootTree instance, then its parent is BinaryTree.empty.

BinaryTree.empty should not have a parent attribute. Assume that every GrootTree instance is a branch of at most one other GrootTree instance and not a branch of any other kind of tree.

Fill in the blanks below so that the parent attribute is set correctly. You may not need to use all of the lines. Indentation is allowed. You *should not* include any assert statements. Using your solution, the doctests for fib\_groot should pass. The BinaryTree class appears on your study guide.

Hint: A picture of fib\_groot(3) appears on the next page.

```
class GrootTree(BinaryTree):
    """A binary tree with a parent."""
    def __init__(self, entry, left=BinaryTree.empty, right=BinaryTree.empty):
        BinaryTree.__init__(self, entry, left, right)
        self.parent = BinaryTree.Empty
        for b in [left, right]:
            if b is not BinaryTree.empty:
                b.parent = self
def fib_groot(n):
    """Return a Fibonacci GrootTree.
    >>> t = fib_groot(3)
    >>> t.entry
    >>> t.parent.is_empty
   >>> t.left.parent.entry
    >>> t.right.left.parent.entry
    >>> t.right.left.parent.right.parent.entry
    1
    .....
    if n == 0 or n == 1:
        return GrootTree(n)
    else:
        left, right = fib_groot(n-2), fib_groot(n-1)
        return GrootTree(left.entry + right.entry, left, right)
```

(b) (4 pt) Fill in the blanks of the implementation of paths, a function that takes two arguments: a GrootTree instance g and a list s. It returns the number of paths through g whose entries are the elements of s. A path through a GrootTree can extend either to a branch or its parent.

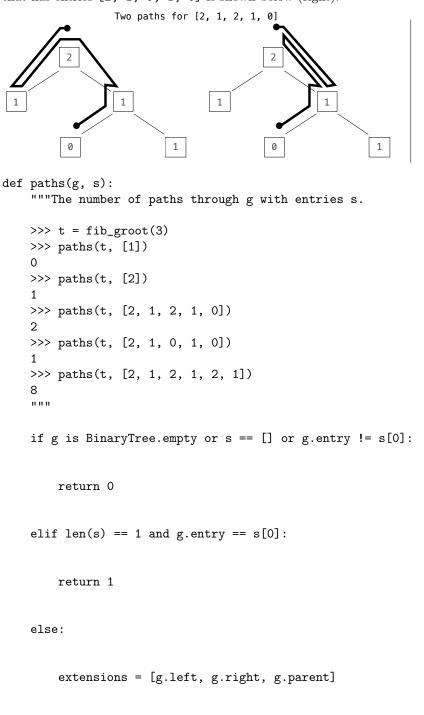
You may assume that the GrootTree class is implemented correctly and that the list s is non-empty.

The two paths that have entries [2, 1, 2, 1, 0] in fib\_groot(3) are shown below (left). The one path that has entries [2, 1, 0, 1, 0] is shown below (right).

One path for [2, 1, 0, 1, 0]

1

1



return sum(paths(x, s[1:]) for x in extensions)

#### 5. (8 points) Abstraction and Growth

(a) (6 pt) Your project partner has invented an abstract representation of a sequence called a slinky, which uses a transition function to compute each element from the previous element. A slinky explicitly stores only those elements that cannot be computed by calling transition, using a starts dictionary. Each entry in starts is a pair of an index key and an element value. See the doctests for examples.

Help your partner fix this implementation by crossing out as many lines as possible, but leaving a program that passes the doctests. Do not change the doctests. The program continues onto the following page.

```
def length(slinky):
    return slinky[0]
def starts(slinky):
    return slinky[1]
def transition(slinky):
    return slinky[2]
def slinky(elements, transition):
    """Return a slinky containing elements using transition.
    >>> s = slinky(range(3, 10), lambda x: x+1)
    >>> length(s)
    7
    >>> starts(s)
    {0: 3}
    >>> get(s, 2)
    >>> t = slinky([2, 4, 10, 20, 40], lambda x: 2*x)
    >>> starts(t)
    \{0: 2, 2: 10\}
    >>> get(t, 3)
    20
    >>> slinky([], abs)
    [0, {}, <built-in function abs>]
    >>> slinky([5, 4, 3], abs)
    [3, {0: 5, 1: 4, 2: 3}, <built-in function abs>]
    11 11 11
    starts = {}
    for index in range(len(elements)):
        if index == 0 or elements[index] != transition(elements[index-1]):
            starts[index] = elements[index]
    return [len(elements), starts, transition]
```

```
def get(slinky, index):
    """Return the element at index of slinky."""
    start = index
    while start not in starts(slinky):
        start = start - 1
    value = starts(slinky)[start]
    while start < index:
        value = transition(slinky)(value)
        start = start + 1
    return value</pre>
```

- (b) (2 pt) Circle the Θ expression below that describes the number of operations required to compute slinky(elements, transition), assuming that
  - n is the initial length of elements,
  - d is the final length of the starts dictionary created,
  - the transition function requires constant time,
  - the pop method of a list requires constant time,
  - the len function applied to a list requires linear time,
  - the len function applied to a range requires constant time,
  - adding or updating an entry in a dictionary requires constant time,
  - getting an element from a list by its index requires constant time,
  - creating a list requires time that is proportional to the length of the list.

 $\Theta(1)$   $\Theta(n)$   $\Theta(d)$   $\Theta(n^2)$   $\Theta(d^2)$   $\Theta(n \cdot d)$