1 More Recursion

Questions

1.1 In discussion 1, we implemented the function is_prime, which takes in a positive integer and returns whether or not that integer is prime, iteratively.

Now, let’s implement it recursively! As a reminder, an integer is considered prime if it has exactly two unique factors: 1 and itself.

```python
def is_prime(n):
    """
    >>> is_prime(7)
    True
    >>> is_prime(10)
    False
    >>> is_prime(1)
    False
    """

def prime_helper(______________):
    if ________________:
        ________________
    elif ________________:
        ________________
    else:
        ________________

    return ________________
```
def prime_helper(index):
    if index == n:
        return True
    elif n % index == 0 or n == 1:
        return False
    else:
        return prime_helper(index + 1)

return prime_helper(2)
1.2 Define a function `make_fn_repeater` which takes in a one-argument function \( f \) and an integer \( x \). It should return another function which takes in one argument, another integer. This function returns the result of applying \( f \) to \( x \) this number of times.

Make sure to use recursion in your solution.

```python
def make_func_repeater(f, x):
    
    >>> incr_1 = make_func_repeater(lambda x: x + 1, 1)
    >>> incr_1(2) #same as f(f(x))
    3
    >>> incr_1(5)
    6
    
    def repeat(___________________):
        
        if ________________:
            return __________________

        else:
            return __________________

    return __________________

def repeat(i):
    if i == 0:
        return x
    else:
        return f(repeat(i - 1))
return repeat
```
Consider a function that requires more than one recursive call. A simple example is the recursive \texttt{fibonacci} function:

\begin{verbatim}
def fib(n):
    if n == 0:
        return 0
    elif n == 1:
        return 1
    else:
        return fib(n - 1) + fib(n - 2)
\end{verbatim}

This type of recursion is called \textit{tree recursion}, because it makes more than one recursive call in its recursive case. If we draw out the recursive calls, we see the recursive calls in the shape of an upside-down tree:

![Tree Recursion Diagram](image)

We could, in theory, use loops to write the same procedure. However, problems that are naturally solved using tree recursive procedures are generally difficult to write iteratively. It is sometimes the case that a tree recursive problem also involves iteration: for example, you might use a while loop to add together multiple recursive calls.

As a general rule of thumb, whenever you need to try multiple possibilities at the same time, you should consider using tree recursion.

\textbf{How to diagram Tree Recursion}

\textbf{Questions}

2.1 I want to go up a flight of stairs that has \(n\) steps. I can either take 1 or 2 steps each time. How many different ways can I go up this flight of stairs? Write a function \texttt{count_stair_ways} that solves this problem for me. Assume \(n\) is positive.

Before we start, what’s the base case for this question? What is the simplest input?

When there is only 1 step, there is only one way to go up the stair. When there are two steps, we can go up in two ways: take a two-step, or take 2 one-steps.
What do count_stair_ways(n - 1) and count_stair_ways(n - 2) represent?

count_stair_ways(n - 1) represents the number of different ways to go up the first \( n - 1 \) stairs. count_stair_ways(n - 2) represents the number of different ways to go up the first \( n - 2 \) stairs. Our base cases will take care of the remaining 1 or 2 steps.

Use those two recursive calls to write the recursive case:

```python
def count_stair_ways(n):
    if n == 1:
        return 1
    elif n == 2:
        return 2
    return count_stair_ways(n-1) + count_stair_ways(n-2)
```

Video walkthrough (Leap of Faith)
Video Walkthrough (Diagramming Trees)

2.2 Consider a special version of the count_stairways problem, where instead of taking 1 or 2 steps, we are able to take up to and including \( k \) steps at a time.

Write a function count_k that figures out the number of paths for this scenario. Assume \( n \) and \( k \) are positive.

```python
def count_k(n, k):
    """
    >>> count_k(3, 3) # 3, 2 + 1, 1 + 2, 1 + 1 + 1
    4
    >>> count_k(4, 4)
    8
    >>> count_k(10, 3)
    274
    >>> count_k(300, 1) # Only one step at a time
    1
    """
    if n == 0:
        return 1
    elif n < 0:
        return 0
    else:
        total = 0
```
Recursion & Tree Recursion

i = 1

while i <= k:
    total += count_k(n - i, k)
    i += 1

return total

Video Walkthrough
2.3 Here’s a part of the Pascal’s triangle:

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<tr>
<th>Column: 0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>...</th>
</tr>
</thead>
<tbody>
<tr>
<td>Row 0:</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 1:</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 2:</td>
<td>1</td>
<td>2</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Row 3:</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Row 4:</td>
<td>1</td>
<td>4</td>
<td>6</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Every number in Pascal’s triangle is defined as the sum of the item above it and the item that is directly to the upper left of it, use 0 if the entry is empty. Define the procedure `pascal(row, column)` which takes a row and a column, and finds the value at that position in the triangle.

```python
def pascal(row, column):
    if column == 0:
        return 1
    elif row == 0:
        return 0
    else:
        return pascal(row - 1, column) + \  
pascal(row - 1, column - 1)
```

**Background:** Pascal’s triangle is a useful recursive definition that tells us the coefficients in the expansion of the polynomial \((x + a)^n\). Each element in the triangle has a coordinate, given by the row it is on and its position in the row (which you could call its column).