Cheatsheets / **Algorithmic Concepts**

Recursion

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TOPICS
- **Recursion**
- Algorithmic Complexity

Base Case of a Recursive Function

A recursive function should have a base case with a condition that stops the function from recursing indefinitely. In the example, the base case is a condition evaluating a negative or zero value to be true.

```
function countdown(value)
  if value is negative or zero
    print "done"
  otherwise if value is greater than zero
    print value
    call countdown with (value-1)
```

Recursive Step in Recursive Function

A recursive function should have a **recursive step** which calls the recursive function with some input that brings it closer to its base case. In the example, the recursive step is the call to `countdown()` with a decremented value.

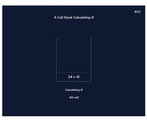
```
def countdown(value):
  if value <= 0:
    print("done")
  else:
    print(value)
    countdown(value-1)  #recursive step
```

What is Recursion

Recursion is a strategy for solving problems by defining the problem in terms of itself. A recursive function consists of two basic parts: the base case and the recursive step.

Call Stack in Recursive Function

Programming languages use a facility called a **call stack** to manage the invocation of recursive functions. Like a stack, a call stack for a recursive function calls the last function in its stack when the **base case** is met.



Big-O Runtime for Recursive Functions

The big-O runtime for a recursive function is equivalent to the number of recursive function calls. This value varies depending on the complexity of the algorithm of the recursive function. For example, a recursive function of input N that is called N times will have a runtime of O(N). On the other hand, a recursive function of input N that calls itself twice per function may have a runtime of O(2^N).

Weak Base Case in Recursive Function

A recursive function with a weak base case will not have a condition that will stop the function from recursing, causing the function to run indefinitely. When this happens, the call stack will overflow and the program will generate a *stack overflow* error.

Execution Context of a Recursive Function

An execution context of a recursive function is the set of arguments to the recursive function call. Programming languages use execution contexts to manage recursive functions.

Stack Overflow Error in Recursive Function

A recursive function that is called with an input that requires too many iterations will cause the call stack to get too large, resulting in a stack overflow error. In these cases, it is more appropriate to use an iterative solution. A recursive solution is only suited for a problem that does not exceed a certain number of recursive calls.

For example, `myfunction()` below throws a stack overflow error when an input of 1000 is used.

```
def myfunction(n):
  if n == 0:
    return n
  else:
    return myfunction(n-1)

myfunction(1000)  #results in stack overflow error
```

Fibonacci Sequence

A Fibonacci sequence is a mathematical series of numbers such that each number is the sum of the two preceding numbers, starting from 0 and 1.

```
Fibonacci sequence: 0, 1, 1, 2, 3, 5, 8, 13, 21,
...
```

Call Stack Construction in While Loop

A call stack with execution contexts can be constructed using a `while` loop, a `list` to represent the call stack and a `dictionary` to represent the execution contexts. This is useful to mimic the role of a call stack inside a recursive function.

Binary Search Tree

In Python, a binary search tree is a recursive data structure that makes sorted lists easier to search. Binary search trees:

- Reference two children at most per tree node.
- The "left" child of the tree must contain a value lesser than its parent.
- The "right" child of the tree must contain a value greater than it's parent.

```
    5
   / \
  /   \
 3     8
/ \   / \
2  4 7   9
```

Recursion and Nested Lists

A nested list can be traversed and flattened using a recursive function. The base case evaluates an element in the list. If it is not another list, the single element is appended to a flat list. The recursive step calls the recursive function with the nested list element as input.

```
def flatten(mylist):
  flatlist = []
  for element in mylist:
    if type(element) == list:
      flatlist += flatten(element)
    else:
      flatlist += element
  return flatlist

print(flatten(['a', ['b', ['c', ['d']], 'e'],
'f']))
# returns ['a', 'b', 'c', 'd', 'e', 'f']
```

Fibonacci Recursion

Computing the value of a Fibonacci number can be implemented using recursion. Given an input of index N, the recursive function has two base cases – when the index is zero or 1. The recursive function returns the sum of the index minus 1 and the index minus 2.

The Big-O runtime of the Fibonacci function is O(2^N).

```
def fibonacci(n):
  if n <= 1:
    return n
  else:
    return fibonacci(n-1) + fibonacci(n-2)
```

Modeling Recursion as Call Stack

One can model recursion as a `call stack` with `execution contexts` using a `while` loop and a Python `list`. When the `base case` is reached, print out the call stack `list` in a LIFO (last in first out) manner until the call stack is empty.

Using another `while` loop, iterate through the call stack `list`. Pop the last item off the list and add it to a variable to store the accumulative result.

Print the result.

```
def countdown(value):
  call_stack = []
  while value > 0 :
    call_stack.append({"input":value})
    print("Call Stack:",call_stack)
    value -= 1
  print("Base Case Reached")
  while len(call_stack) != 0:
    print("Popping {} from call
stack".format(call_stack.pop()))
    print("Call Stack:",call_stack)
countdown(4)
'''
Call Stack: [{'input': 4}]
Call Stack: [{'input': 4}, {'input': 3}]
Call Stack: [{'input': 4}, {'input': 3}, {'input':
2}]
Call Stack: [{'input': 4}, {'input': 3}, {'input':
2}, {'input': 1}]
Base Case Reached
Popping {'input': 1} from call
stack
Call Stack: [{'input': 4}, {'input': 3}, {'input':
2}]
Popping {'input': 2} from call
stack
Call Stack: [{'input': 4}, {'input': 3}]
Popping {'input': 3} from call stack
Call Stack: [{'input':
4}]
Popping {'input': 4} from call stack
Call Stack: []
'''
```

Recursion in Python

In Python, a recursive function accepts an argument and includes a condition to check whether it matches the base case. A recursive function has:

- Base Case - a condition that evaluates the current input to stop the recursion from continuing.
- Recursive Step - one or more calls to the recursive function to bring the input closer to the base case.

```
def countdown(value):
  if value <= 0:   #base case
    print("done")
  else:
    print(value)
    countdown(value-1)  #recursive case
```

Build a Binary Search Tree

To build a binary search tree as a recursive algorithm do the following:

```
BASE CASE:
If the list is empty, return "No Child" to
show that there is no node.

RECURSIVE STEP:
1. Find the middle index of the list.
2. Create a tree node with the value of
the middle index.
3. Assign the tree node's left child to
a recursive call with the left half of
list as input.
4. Assign the tree node's right child to
a recursive call with the right half of
list as input.
5. Return the tree node.
```

```
def build_bst(my_list):
  if len(my_list) == 0:
    return "No Child"

  middle_index = len(my_list) // 2
  middle_value = my_list[middle_index]

  print("Middle index: {}".format(middle_index))
  print("Middle value: {}".format(middle_value))

  tree_node = {"data": middle_value}
  tree_node["left_child"] = build_bst(my_list[
: middle_index])
  tree_node["right_child"]
= build_bst(my_list[middle_index + 1 : ])

  return tree_node

sorted_list = [12, 13, 14, 15, 16]
binary_search_tree = build_bst(sorted_list)
print(binary_search_tree)
```

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