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133. Clone Graph

Nov. 4, 2019 | 48.4K views

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Given a reference of a node in a **connected** undirected graph.

Return a **deep copy** (clone) of the graph.

Each node in the graph contains a val (`int`) and a list (`List[Node]`) of its neighbors.

```
class Node {
    public int val;
    public List<Node> neighbors;
}
```

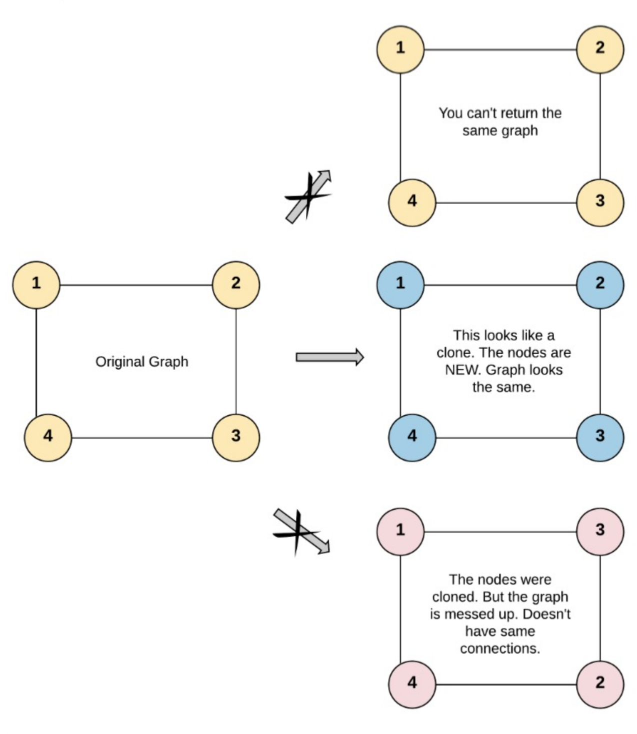
Test case format:

For simplicity sake, each node's value is the same as the node's index (1-indexed). For example, the first node with `val = 1`, the second node with `val = 2`, and so on. The graph is represented in the test case using an adjacency list.

Adjacency list is a collection of unordered **lists** used to represent a finite graph. Each list describes the set of neighbors of a node in the graph.

The given node will always be the first node with `val = 1`. You must return the **copy of the given node** as a reference to the cloned graph.

Example 1:




```
Input: adjList = [[2,4],[1,3],[2,4],[1,3]]
Output: [[2,4],[1,3],[2,4],[1,3]]
Explanation: There are 4 nodes in the graph.
1st node (val = 1)'s neighbors are 2nd node (val = 2) and 4th node (val = 4).
2nd node (val = 2)'s neighbors are 1st node (val = 1) and 3rd node (val = 3).
3rd node (val = 3)'s neighbors are 2nd node (val = 2) and 4th node (val = 4).
4th node (val = 4)'s neighbors are 1st node (val = 1) and 3rd node (val = 3).
```

Example 2:


```
Input: adjList = [[]]
Output: [[]]
Explanation: Note that the input contains one empty list. The graph consists of only
```

Example 3:

```
Input: adjList = []
Output: []
Explanation: This an empty graph, it does not have any nodes.
```

Example 4:


```
Input: adjList = [[2],[1]]
Output: [[2],[1]]
```

Constraints:

- `1 <= Node.val <= 100`
- `Node.val` is unique for each node.
- Number of Nodes will not exceed 100.
- There is no repeated edges and no self-loops in the graph.
- The Graph is connected and all nodes can be visited starting from the given node.

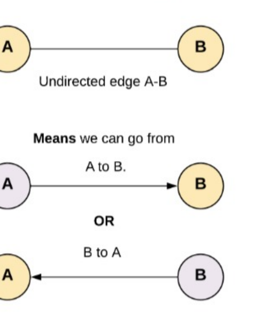
Solution

Approach 1: Depth First Search

Intuition

> Note: As we can see this question has garnered a lot of negative reviews. It has a lot more dislikes than the likes. We have tried to improve the problem statement to make it more understandable. However, these are the kinds of situations you might get into in an interview when the problem statement might look a little absurd. What is important then is to ask the interviewer to clarify the problem. This problem statement was confusing to me as well initially and that's why I decided to write the solution hoping to clarify most of the doubts that the readers might have had.

The basic intuition for this problem is to just copy as we go. We need to understand that we are dealing with a graph and this means a node could have any number of neighbors. This is why `neighbors` is a list. What is also crucial to understand is that we don't want to get stuck in a cycle while we are traversing the graph. According to the problem statement, any given undirected edge could be represented as two directional edges. So, if there is an undirected edge between node `A` and node `B`, the graph representation for it would have a `directed` edge from `A to B` and another from `B to A`. After all, an undirected graph is a set of nodes that are connected together, where all the edges are bidirectional. How else would you say that `A` could be reached from `B` and `B` could be reached from `A`?

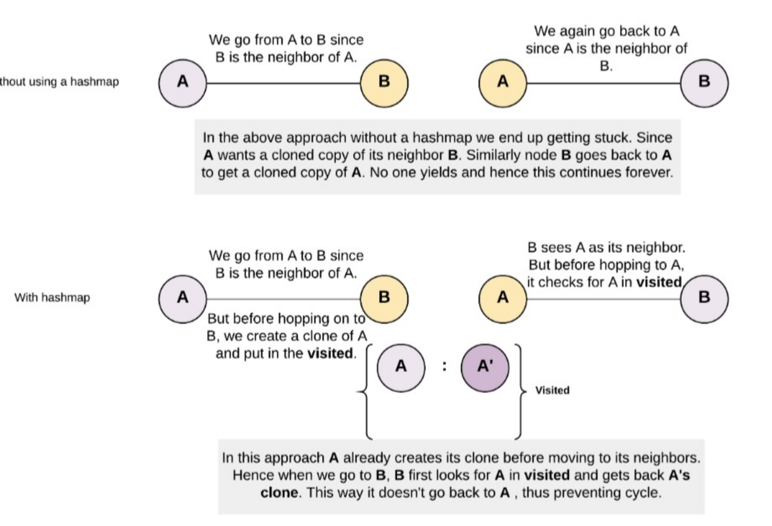


To avoid getting stuck in a loop we would need some way to keep track of the nodes which have already been copied. By doing this we don't end up traversing them again.

Algorithm

1. Start traversing the graph from the given node.
2. We would take a hash map to store the reference of the copy of all the nodes that have already been visited and cloned. The `key` for the hash map would be the node of the original graph and corresponding `value` would be the corresponding cloned node of the cloned graph. If the node already exists in the `visited` we return corresponding stored reference of the cloned node.

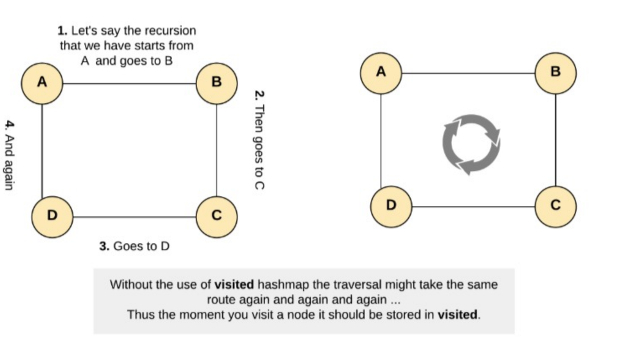
   For a given edge `A - B`, since `A` is connected to `B` and `B` is also connected to `A` if we don't use `visited` we will get stuck in a cycle.

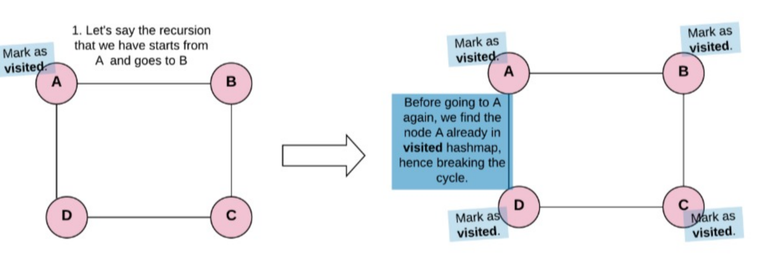


3. If we don't find the node in the `visited` hash map, we create a copy of it and put it in the hash map. Note, how it's important to create a copy of the node and add to the hash map before entering recursion.

   ```
   clone_node = Node(node.val, [])
   visited[node] = clone_node
   ```

   In the absence of such an ordering, we would be caught in the recursion because on encountering the node again in somewhere down the recursion again, we will be traversing it again thus getting into cycles.





4. Now make the recursive call for the neighbors of the `node`. Pay attention to how many recursion calls we will be making for any given `node`. For a given `node` the number of recursive calls would be equal to the number of its neighbors. Each recursive call made would return the clone of a neighbor. We will prepare the list of these clones returned and put into neighbors of clone `node` which we had created earlier. This way we will have cloned the given `node` and it's `neighbors`.

> Tip: Recursion could get a bit cumbersome to grasp, if you try to get into every call yourself and try to see what's happening. And why look at every call when every call does the same thing with different inputs. So, you just worry about ONE such call and let the recursion do the rest. And of course always handle the base case or the termination condition of the recursion. Otherwise how would it end?

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```python
"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, neighbors):
        self.val = val
        self.neighbors = neighbors
"""
class Solution(object):

    def __init__(self):
        # Dictionary to save the visited node and it's respective clone
        # as key and value respectively. This helps to avoid cycles.
        self.visited = {}

    def cloneGraph(self, node):
        """
        :type node: Node
        :rtype: Node
        """
        if not node:
            return node

        # If the node was already visited before.
        # Return the clone from the visited dictionary.
        if node in self.visited:
            return self.visited[node]
```

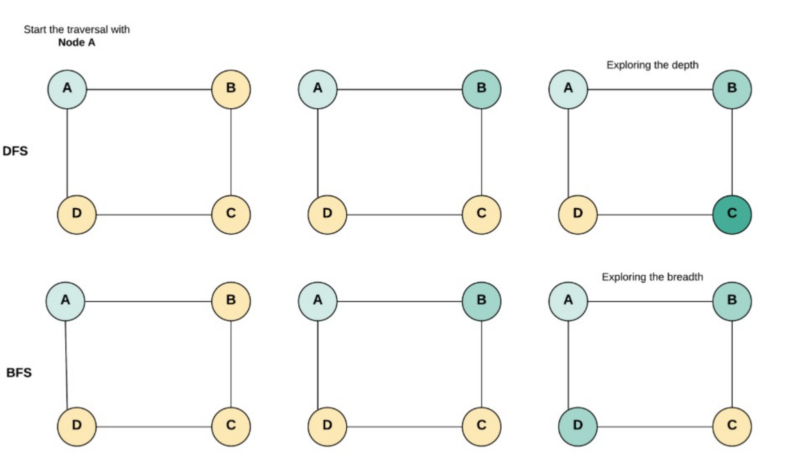
Complexity Analysis

- Time Complexity: $O(N)$ since we process each node exactly once.
- Space Complexity: $O(N)$. This space is occupied by the `visited` hash map and in addition to that, space would also be occupied by the recursion stack since we are adopting a recursive approach here. The space occupied by the recursion stack would be equal to $O(H)$ where H is the height of the graph. Overall, the space complexity would be $O(N)$.

Approach 2: Breadth First Search

Intuition

We could agree DFS is a good enough solution for this problem. However, if the recursion stack is what we are worried about then DFS is not our best bet. Sure, we can write an iterative version of depth first search by using our own stack. However, we also have the BFS way of doing iterative traversal of the graph and we'll be exploring that solution as well.



The difference is only in the traversal of DFS and BFS. As the name says it all, DFS explores the depths of the graph first and BFS explores the breadth. Based on the kind of graph we are expecting we can chose one over the other. We would need the `visited` hash map in both the approaches to avoid cycles.

Algorithm

1. We will use a hash map to store the reference of the copy of all the nodes that have already been visited and copied. The `key` for the hash map would be the node of the original graph and corresponding `value` would be the corresponding cloned node of the cloned graph. The `visited` is used to prevent cycles and get the cloned copy of a node.
2. Add the first node to the queue. Clone the first node and add it to `visited` hash map.
3. Do the BFS traversal.
   - Pop a node from the front of the queue.
   - Visit all the neighbors of this node.
   - If any of the neighbors was already visited then it must be present in the `visited` dictionary. Get the clone of this neighbor from `visited` in that case.
   - Otherwise, create a clone and store in the `visited`.
   - Add the clones of the neighbors to the corresponding list of the clone node.

Java | Python | Copy

```python
"""
# Definition for a Node.
class Node(object):
    def __init__(self, val, neighbors):
        self.val = val
        self.neighbors = neighbors
"""
from collections import deque
class Solution(object):

    def cloneGraph(self, node):
        """
        :type node: Node
        :rtype: Node
        """

        if not node:
            return node

        # Dictionary to save the visited node and it's respective clone
        # as key and value respectively. This helps to avoid cycles.
        visited = {}

        # Put the first node in the queue
        queue = deque([node])
        # Clone the node and put it in the visited dictionary.
        visited[node] = Node(node.val, [])
```

Complexity Analysis

- Time Complexity : $O(N)$ since we process each node exactly once.
- Space Complexity : $O(N)$. This space is occupied by the `visited` dictionary and in addition to that, space would also be occupied by the queue since we are adopting the BFS approach here. The space occupied by the queue would be equal to $O(W)$ where W is the width of the graph. Overall, the space complexity would be $O(N)$.

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Preview Post

box_of_donuts ★433 January 30, 2020 12:17 PM
The time complexity analysis for both approaches is incorrect as it does not take into account the number of edges. For example, for a complete graph with edges between all pairs of nodes, the time complexity is O(N^2). A more accurate time complexity is O(N+M) where M is the number of edges in the graph.
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gauravsin ★41 December 23, 2019 2:11 AM
@godayaldivya that tip for DFS is gold. It took me a while to learn to put myself in the shoes of a sub-problem state on the stack and trust that return from the recursive call will give me what I need instead of going into the call myself.
That being said, creating a call stack and visualizing the recursion tree can instill this trust. However, isolating the sub-problems from the bigger picture as in memoized DP approaches is very valuable to
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ogremergo ★15 November 22, 2019 10:26 PM
Thanks for your amazing article.
14 Share Reply

Ek-Do-Teen ★48 February 19, 2020 11:40 AM
The time complexity for DFS should be O(V+E)
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hormigas ★59 December 26, 2019 2:37 AM
How would a HashMap work here, given that we don't know how the hashCode method for the class `Node` has been implemented ? What if two nodes hash to the same value ? I ask this since we have absolutely no details on how the hashCode is calculated for a `Node`
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somename ★3 May 25, 2020 12:03 PM
RE "As we can see this question has garnered a lot of negative reviews"

I don't think this is because it's hard or confusing, etc. The problem is that the problem states that we're given a node as input, whereas the test cases / submission actually pass you a list of edges.
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lightning_me ★10 April 17, 2020 10:56 AM Report
dfs a graph
time comp: V + E
space comp: V
V in number of vertices
E is number of edges
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chadcromwell ★11 April 3, 2020 7:38 AM
We need to take edges into account for the time complexity since we're calling a for loop and iterating all neighbours no matter what. As the input size grows, this will cause the running time to increase. We are still checking the HashMap for these neighbors.

Also, we're calling HashMap's put() method so O(n+m) is still not fully accurate.
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fast_c0dr ★20 March 20, 2020 7:12 AM
Thank you for your work. I do not understand why a Node cannot maintain a `isVisited` variable?!
Maintaining a HashMap for a simple flag is too cumbersome
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theseungjin ★164 January 24, 2020 4:41 AM
Very thoughtful explanations, thank you!
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