23. Merge k Sorted Lists

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Description (/problems/merge-k-sorted-lists/description/) Hints (/problems/merge-k-sorted-lists/hints/) Submissions (/problems/merge-k-sc

Quick Navigation View in Article (/articles/merge-k-sorted-lists)

Notes

Solution

Approach 1: Brute Force

Intuition & Algorithm

- Traverse all the linked lists and collect the values of the nodes into an array.
- Sort and iterate over this array to get the proper value of nodes.
- Create a new sorted linked list and extend it with the new nodes.

As for sorting, you can refer here (https://www.cs.cmu.edu/~adamchik/15-121/lectures/Sorting%20Algorithms/sorting.html) for more about sorting algorithms.

Python Copy

```
class Solution(object):
    def mergeKLists(self, lists):
        """
        :type lists: List[ListNode]
        :rtype: ListNode
        """
        self.nodes = []
        head = point = ListNode(0)
        for l in lists:
            while l:
                self.nodes.append(l.val)
                l = l.next
        for x in sorted(self.nodes):
            point.next = ListNode(x)
            point = point.next
        return head.next
```

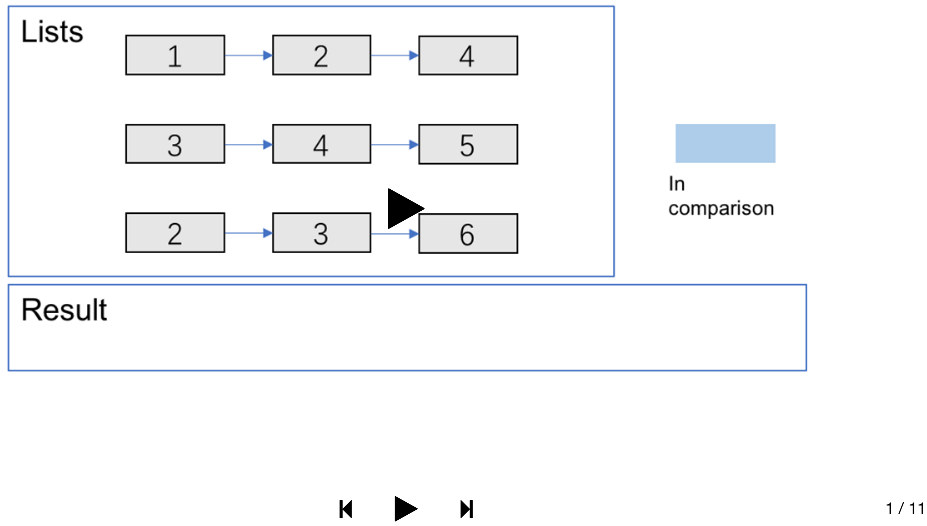
Complexity Analysis

- Time complexity : $O(N \log N)$ where N is the total number of nodes.
  - Collecting all the values costs $O(N)$ time.
  - A stable sorting algorithm costs $O(N \log N)$ time.
  - Iterating for creating the linked list costs $O(N)$ time.
- Space complexity : $O(N)$.
  - Sorting cost $O(N)$ space (depends on the algorithm you choose).
  - Creating a new linked list costs $O(N)$ space.

Approach 2: Compare one by one

Algorithm

- Compare every k nodes (head of every linked list) and get the node with the smallest value.
- Extend the final sorted linked list with the selected nodes.



Complexity Analysis

- Time complexity : $O(kN)$ where k is the number of linked lists.
  - Almost every selection of node in final linked costs $O(k)$ (k-1 times comparison).
  - There are N nodes in the final linked list.
- Space complexity :
  - $O(n)$ Creating a new linked list costs $O(n)$ space.
  - $O(1)$ It's not hard to apply in-place method - connect selected nodes instead of creating new nodes to fill the new linked list.

Approach 3: Optimize Approach 2 by Priority Queue

Algorithm

Almost the same as the one above but optimize the **comparison process** by **priority queue**. You can refer here (https://en.wikipedia.org/wiki/Priority_queue) for more information about it.

Python Copy

Complexity Analysis

- Time complexity : $O(N \log k)$ where k is the number of linked lists.
  - The comparison cost will be reduced to $O(\log k)$ for every pop and insertion to priority queue. But finding the node with the smallest value just costs $O(1)$ time.
  - There are N nodes in the final linked list.
- Space complexity :
  - $O(n)$ Creating a new linked list costs $O(n)$ space.
  - $O(k)$ The code above present applies in-place method which cost $O(1)$ space. And the priority queue (often implemented with heaps) costs $O(k)$ space (it's far less than N in most situations).

Approach 4: Merge lists one by one

Algorithm

Convert merge k lists problem to merge 2 lists (k-1) times. Here is the merge 2 lists (https://leetcode.com/problems/merge-two-sorted-lists/description/) problem page.

Complexity Analysis

- Time complexity : $O(kN)$ where k is the number of linked lists.
  - We can merge two sorted linked list in $O(n)$ time where n is the total number of nodes in two lists.
  - Sum up the merge process and we can get: $O(\sum_{i=1}^{k-1}(i * (\frac{N}{k}) + \frac{N}{k})) = O(kN)$.
- Space complexity : $O(1)$
  - We can merge two sorted linked list in $O(1)$ space.

Approach 5: Merge with Divide And Conquer

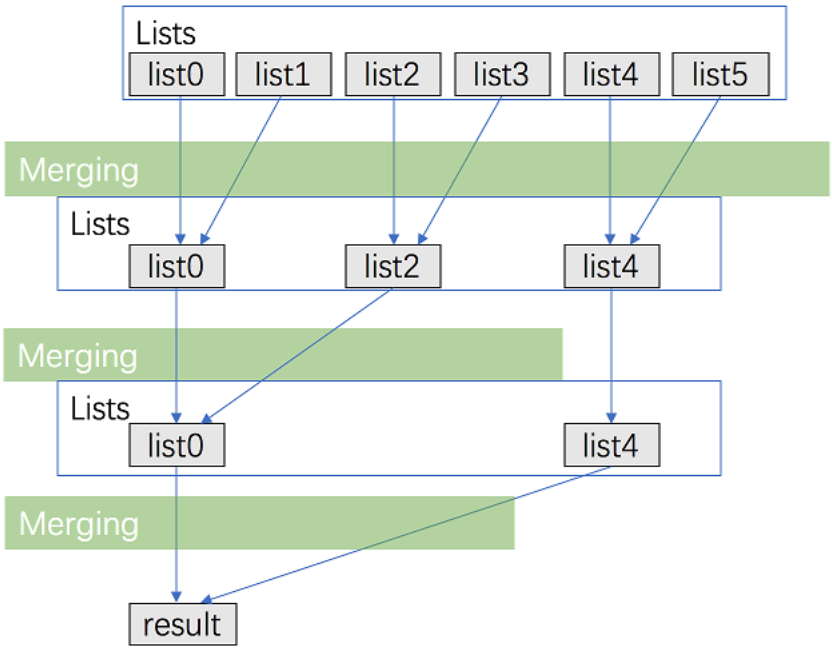
Intuition & Algorithm

This approach walks alongside the one above but is improved a lot. We don't need to traverse most nodes many times repeatedly

- Pair up k lists and merge each pair.

- After the first pairing, k lists are merged into $k/2$ lists with average $2N/k$ length, then $k/4$, $k/8$ and so on.
- Repeat this procedure until we get the final sorted linked list.

Thus, we'll traverse almost N nodes per pairing and merging, and repeat this procedure about $\log_2 k$ times.



Python Copy

```python
class Solution(object):
    def mergeKLists(self, lists):
        """
        :type lists: List[ListNode]
        :rtype: ListNode
        """
        amount = len(lists)
        interval = 1
        while interval < amount:
            for i in range(0, amount - interval, interval * 2):
                lists[i] = self.merge2Lists(lists[i], lists[i + interval])
            interval *= 2
        return lists[0] if amount > 0 else lists

    def merge2Lists(self, l1, l2):
        head = point = ListNode(0)
        while l1 and l2:
            if l1.val <= l2.val:
                point.next = l1
                l1 = l1.next
            else:
                point.next = l2
                l2 = l1
                l1 = point.next.next
            point = point.next
        if not l1:
            point.next=l2
```

Complexity Analysis

- Time complexity : $O(N \log k)$ where k is the number of linked lists.
  - We can merge two sorted linked list in $O(n)$ time where n is the total number of nodes in two lists.
  - Sum up the merge process and we can get: $O\left(\sum_{i=1}^{log_2 k} N\right) = O(N \log k)$
- Space complexity : $O(1)$
  - We can merge two sorted linked lists in $O(1)$ space.