write-up-4-3.md

Q3 Comparing dictionary structures

1. **Hypothesis**: In theory, the complexity analysis of the insertion operation for the hash table and binary tree are O(1) and O(log(n)), respectively. Thus the hash table should be much faster than the tree-based dictionary. The latter however produces no duplicate keys so there would be no collisions. The advantage of the tree-based dictionary is not speed but to reduce memory consumption, and to have better worst-case guarantees. I have no clue to estimate the dividing point for those two dictionaries for the running efficiency. And I guess the hash table should be faster than the tree-based container from the beginning. And it can be much faster with a larger size of numbers. Since the tree-based container spends extra time to maintain the order of the keys.

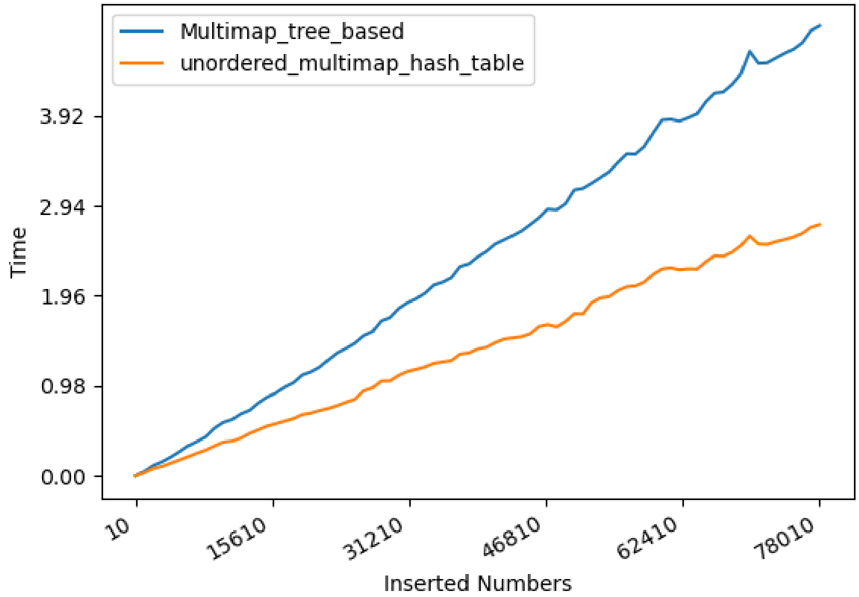
2. **Methods**: The github link is as follows:

https://github.com/liecn/algorithms/blob/master/CSE_830/hw4/hw4_3.cpp

- We generate the random series of numbers using the pseudo-random generator **std::mt19937** with the real distribution **std::uniform_int_distribution**.

- We achieve the **std::multimap** and **std::unordered_multimap** and test the insertion operation.

- We test different sizes of numbers and run 100 times for each size, delivering the accumulated time as the final outputs.



3. **Results**:

4. **Discussion**: Consistent with the **Hypothesis**, the graph indicates the hash table (**std::unordered_multimap**) should be faster than the tree-based container (**std::multimap**) from the beginning.

5. **Conclusions**: Under the conditions tested with the current implementation, both dictionaries spend the linear time for the insertion operation. While the tree-based container consumes extra time to maintain the order of the stored keys for insertion.