Advanced Programming Exam

2021-22 Autumn Session

Problem description

Red-Black Trees are binary search trees satisfying the following conditions:

- every node is either red or black;
- the root is black
- every leaf (`NIL`) is black;
- if a node is red, then its children are black;
- for each node x, all the simple paths from x to descendant leaves contains the same number of black nodes.

Thanks to the mentioned properties, it is possible to insert, delete, and search a value in a red-black tree in time $O(\log n)$ (e.g., see [1]).

Assignment

Implement the generic classes `RBTree<T, CMP=std::less<T>>` and `RBTree<T, CMP=std::less<T>>::const_iterator` to represent red-black trees and their constant iterators.

`const_iterator` must provide the following public methods:

- `const T& operator*() const` to get the value associated to the iterator;
- `const T* operator->() const` to access to the value associated to the iterator;
- `const_iterator& operator++()` to pre-increment the iterator;
- `const_iterator operator++(int)` to post-increment the iterator;
- `bool operator==(const const_iterator&) const` to test whether two iterators are equivalent;
- `bool operator!=(const const_iterator&) const` to test whether two iterators are different.

Moreover, `RBTree` must provide the following public methods:

- `void insert(const T& value)` to insert a new value in the tree;
- `bool contains(const T& value) const` to test whether the tree contains a value;
- `bool delete(const T& value)` to delete a value from the tree;
- `RBTree<T, CMP>::const_iterator begin() const` to get a constant tree iterator over all the tree keys;
- `RBTree<T, CMP>::const_iterator end() const` to get the last value for a tree iterator.

Few functions showing the classes features are also requested (e.g., by using the Boost test library).

Exam and Deadline

The exam must occur during the autumn exam session 2021/22, i.e., between Sept. 1 and Sept. 30, 2022. The exam date must be individually scheduled in agreement with the teacher. To plan it, please write to acasagrande@units.it.

The assignment solution must be sent to acasagrande@units.it at least 10 days before the scheduled exam date.

References

[1] Thomas H. Cormen, Charles E. Leiserson, Ronald L. Rivest, and Clifford Stein. *Introduction to Algorithms*. The MIT Press, 2nd edition, 2001.