adamant's blog

C++ STL: Policy based data structures

By adamant, 8 years ago, translation,

Hi everyone! After a relatively long lull, I decided that ~~my contribution growing too slowly~~ the hour has come to please you with another article in the blog *:)*

2 months ago user **Perlik** wrote an article, in which he described a very interesting STL implemented data structure that allows you to quickly perform various operations with substrings. Some time after I tested it on various tasks and, unfortunately, tend to get a negative result — rope was too slow, especially when it came to working with individual elements.

For some time, I forgot about that article. Increasingly, however, I was faced with problems in which it was necessary to implement set with the ability to know ordinal number of item and also to get item by its ordinal number (ie, order statistic in the set). And then I remembered that in the comments to that article, someone mentioned about the mysterious data structure order statistics tree, which supports these two operations and which is implemented in STL (unfortunately only for the GNU C++). And here begins my fascinating acquaintance with policy based data structures, and I want to tell you about them *:)*

Let's get started. In this article I will talk about IMO the most interesting of the implemented structures — tree. We need to include the following headers:

```
#include <ext/pb_ds/assoc_container.hpp> // Common file
#include <ext/pb_ds/tree_policy.hpp> // Including tree_order_statistics_node_update
```

After closer inspection you may find that the last two files contained in the library

```
#include <ext/pb_ds/detail/standard_policies.hpp>
```

Namespace, which we will have to work in newer versions of C++ is called `__gnu_pbds;`, earlier it was called `pb_ds;`

Now let's look at the concrete structure.

The tree-based container has the following declaration:

```
	template<
	typename Key, // Key type
	typename Mapped, // Mapped-policy
	typename Cmp_Fn = std::less<Key>, // Key comparison functor
	typename Tag = rb_tree_tag, // Specifies which underlying data structure to use
	template<
	typename Const_Node_Iterator,
	typename Node_Iterator,
	typename Cmp_Fn_,
	typename Allocator_>
	class Node_Update = null_node_update, // A policy for updating node invariants
	typename Allocator = std::allocator<char> > // An allocator type
	class tree;
```

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Experienced participants may have already noticed that if initialize the template only the first two types, we obtain almost exact copy of the container `map` . Just say, that this container can be `set` , for this you just need to specify the second argument template type as `null_type` (in older versions it is `null_mapped_type`).

By the way `Tag` and `Node_Update` are missing in `map` . Let us examine them in more detail.

`Tag` — class denoting a tree structure, which we will use. There are three base-classes provided in STL for this, it is `rb_tree_tag` (red-black tree), `splay_tree_tag` (splay tree) and `ov_tree_tag` (ordered-vector tree). Sadly, at competitions we can use only red-black trees for this because splay tree and OV-tree using linear-timed split operation that prevents us to use them.

`Node_Update` — class denoting policy for updating node invariants. By default it is set to `null_node_update` , ie, additional information not stored in the vertices. In addition, C++ implemented an update policy `tree_order_statistics_node_update` , which, in fact, carries the necessary operations. Consider them. Most likely, the best way to set the tree is as follows:

```
typedef tree<
int,
null_type,
less<int>,
rb_tree_tag,
tree_order_statistics_node_update>
ordered_set;
```

If we want to get map but not the set, as the second argument type must be used mapped type. Apparently, the tree supports the same operations as the `set` (at least I haven't any problems with them before), but also there are two new features — it is `find_by_order()` and `order_of_key()` . The first returns an iterator to the k-th largest element (counting from zero), the second — the number of items in a set that are strictly smaller than our item. Example of use:

```
    ordered_set X;
    X.insert(1);
    X.insert(2);
    X.insert(4);
    X.insert(8);
    X.insert(16);

    cout<<*X.find_by_order(1)<<endl; // 2
    cout<<*X.find_by_order(2)<<endl; // 4
    cout<<*X.find_by_order(4)<<endl; // 16
    cout<<(end(X)==X.find_by_order(6))<<endl; // true

    cout<<X.order_of_key(-5)<<endl;  // 0
    cout<<X.order_of_key(1)<<endl;   // 0
    cout<<X.order_of_key(3)<<endl;   // 2
    cout<<X.order_of_key(4)<<endl;   // 2
    cout<<X.order_of_key(400)<<endl; // 5
```

Finally I would like to say about the performance of order_statistics_tree in STL. For this, I provide the following table.

Solution\Problem	1028	1090	1521	1439
order_statistics_tree, STL	0.062	0.218	0.296	0.468
Segment tree	0.031	0.078	0.171	0.078 0.859*
Binary Indexed Tree	0.031	0.062	0.062	-

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* The final task requires direct access to the nodes of the tree for the implementation of solutions for O (mlogn). Without it, the solution works in O (mlogn*logn).

As you can see from all this , order_statistics_tree relatively little behind handwritten structures, and at times ahead of them in execution time. At the same time the code size is reduced considerably. Hence we can conclude is that order_statistics_tree — it is good and it can be used in contests.

Besides tree, I also wanted to describe here trie. However , I was confused by some aspects of its implementation, greatly limiting its usefulness in programming olympiads, so I decided not to talk about it. If anyone want he is encouraged to try to learn more about this structure by himself.

Useful links:
— Documentation of pb_ds
— Testing of pb_ds
— Using of pb_ds
— Demonstration of order_statistics_tree
— Demonstration of trie with prefix search
— Operations with intervals with handwritten update policy class
— More examples from that site

P.S. Sorry for my poor English *:)*

stl, k-th order statistic, set, map

+120 ☆ adamant 8 years ago 132

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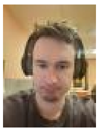
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8 years ago, # | ☆ +12

Example of trie with search of prefix range.
Problem: 1414
Solution: http://ideone.com/6VFNZl
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low_kii_savage

3 years ago, # ^ | ☆ ← Rev. 2 0

Is there a way of counting number of strings in the trie with a certain prefix without iterating through them all?
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daksh_

12 months ago, # ^ | ☆ 0

You augment the trie node to also contain a number. Update this number everytime you insert a string into the trie. To get the number of strings which share the prefix, Just traverse the prefix and output the num in the ending node.
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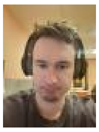
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8 years ago, # | ☆ +17

Возможно, вам покажутся слегка нетривиальными решения деревом отрезков и деревом Фенвика, особенно, задач 1521 и 1439. Скорее всего, позже я также предоставлю статью, в которой опишу некоторые интересные способы использования этих структур, которые редко встречаются.

===

You may be wondered about how I use segment tree and binary indexed tree in my solutions, especially for problems 1521 and 1439. Most likely, later I'll provide an entry about some interesting ways of using this structures, which are quite rare.
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8 years ago, # ^ | ☆ 0

Here it is :)

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