Competitive STL Extensions

Meeting C++ 2018

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- Solving a problem means sending a program to the judging system. The program should pass all the secret test cases within time limit
- Optimal algorithmic complexity is usually enough, especially for C++ solutions
- Solutions are compiled in a judging environment without any additional libraries, with just the stock compiler installation

Standard library

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- Algorithms: `sort`, `lower_bound`, `unique`, `next_permutation`, etc
- Data structures: `{unordered_,}{set,map}`, simpler containers
- GNU C++ specific: `#include <bits/stdc++.h>` includes everything!

popcount: number of set bits

```
int main(int argc, const char* argv[]) {
  static_assert(0 == __builtin_popcount(0));  // wow so constexpr
  static_assert(4 == __builtin_popcount(0b1111));
  static_assert(3 == __builtin_popcount(0b100101));
  return __builtin_popcount(argc);
}
```

godbolts under x86 to

```
main:
        xor     eax, eax
        popcnt  eax, edi
        ret
```

Similarly, `__builtin_clz` and `__builtin_ctz` count leading/trailing zeros

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- Matrix exponentiation: $A^n = E \cdot \underbrace{A \cdot A \cdot \ldots \cdot A}_{n \text{ times}}$, where E is identity matrix
- Integer exponentiation over a modulus:

$$a^n \mod p = 1 \cdot \underbrace{(((a \mod p) \cdot a \mod p) \cdot \ldots \cdot a \mod p)}_{n \text{ multiplications modulo } p}$$

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- If multiplication is associative, this can be done in just $O(\log n)$ multiplications

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```
#include <bits/extc++.h>

constexpr int64_t Modulo = 1000000007;  // a prime number
auto multiply_modulo = [](int64_t a, int64_t b) {
  return a * b % Modulo;
};
// this is required to fully define the operation
// will be called through ADL
int64_t identity_element(decltype(multiply_modulo)) {
  return 1;
}
bool fermat_little_theorem_holds(int64_t x) {  // x^p ≡ x (mod p)
  return __gnu_cxx::power(x, Modulo, multiply_modulo) == x % Modulo;
}
```

Policy-Based Data Structures

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- Shipped with GNU C++ library as an extension within namespace `__gnu_pbds`

PBDS: order statistics tree

- Usual std::set maintains a dynamic sorted sequence. It has methods like

  ```
  iterator set<T>::lower_bound(const T&) const
  ```

  but no methods like

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- Efficient ($O(\log n)$) implementation of these methods would require maintaining additional information in the search tree nodes
- `__gnu_pbds::tree_order_statistics_node_update` is a tree update policy that does exactly that, and enables methods

  `tree::iterator tree::find_by_order(size_t) const`

  and

  `size_t tree::order_of_key(const T&) const`

PBDS: order statistics tree declaration

```cpp
#include <bits/extc++.h>
using namespace __gnu_pbds;

template<typename K, typename V, class Earlier = std::less<K>>
using OrderStatsMap = tree<
  K, V, Earlier,
  rb_tree_tag,  // or splay_tree_tag
  tree_order_statistics_node_update  // extension policy
>;

template<typename K, class Earlier = std::less<K>>
using OrderStatsSet = OrderStatsMap<K, null_type, Earlier>;
```

PBDS: order statistics tree usage

```
OrderStatsSet<int> s;
for (auto k : {12, 505, 30, 100}) {
  s.insert(k);
}

// The order of the keys should be: 12, 30, 100, 505.
assert(12 == *s.find_by_order(0));
assert(100 == *s.find_by_order(2));
assert(s.end() == s.find_by_order(4));

assert(0 == s.order_of_key(10));
assert(1 == s.order_of_key(30));
assert(4 == s.order_of_key(1000));
```

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- There are some lacking utilities that still constrain its dominance
- Most notably, arbitrary precision arithmetics: sometimes it is pragmatic to switch to Python or Java just for big integers

kthxbye

- Thanks!
- More examples:
  `https://github.com/moskupols/competitive-stl-extensions`
- For more info on PBDS see GNU C++ library manual:
  `https://goo.gl/PmR86Z`