
Яндекс

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C++ Contracts

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ISO WG21 national body

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- What the hell is Contracts?
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- Big “O”
- Contracts and algorithms

Contracts

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Contracts – in development feature of the C++ language that allows to specify the function domain.

Contracts — asserts on steroids

```
void push(int x, queue & q);
```

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```
void push(int x, queue & q)
  [[expects: !q.full()]]
  [[ensures: !q.empty()]]
{
  //...
  [[assert: q.is_valid()]];
  //...
}
```

Contracts — asserts on steroids

```
void push(int x, queue & q) [[expects: !q.full()]] [[ensures: !q.empty()]] ;

queue q;

// ...
```

Contracts — asserts on steroids

```
void push(int x, queue & q) [[expects: !q.full()]] [[ensures: !q.empty()]] ;

queue q;

// ...

if (!q.full()) {

    push(10, q); // No need to check

    if (q.empty()) { // Always false

    }

} else {

    push(11, q); // Suspicious!

}
```

Contracts — asserts on steroids

```
void(const std::contract_violation &);


namespace std {
  class contract_violation {
  public:
    int line_number() const noexcept;
    const char * file_name() const noexcept;
    const char * function_name() const noexcept;
    const char * comment() const noexcept;
  };
}
```

<algorithm>

std::sort(beg, end)

Sorts in ascending order:

4	6	9	1	2	5	3	8	7	0	@

std::sort(beg, end)

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4	6	9	1	2	5	3	8	7	0	@

0	1	2	3	4	5	6	7	8	9	@

std::sort(beg, end)

```
template <class RandomAccessIterator>
void sort(RandomAccessIterator beg, RandomAccessIterator end)
    [[expects: beg <= end]]
    [[ensures: is_sorted(beg, end)]]
;
```

Big «O»

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```
for (size_t i = 0; i < N; ++i)                  => O(N)
```

```
for (size_t i = 0; i < N; ++i)
        for (size_t j = 0; j < N; ++j)          => O(N²)
```

Big «O»

N	N*log(N)	N*N
2	2	4
4	8	16
8	24	64
16	64	256
32	160	1,024
64	384	4,096
128	896	16,384
256	2,048	65,536
512	4,608	262,144
1,024	10,240	1,048,576

Big «O»

- std::sort => $O(N*\log_2(N))$

Big «O»

- std::sort => $O(N*\log_2(N))$
- std::stable_sort => $O(N*\log_2^2(N))$

Big «O»

- ~~std::sort~~ => O(N*$\log_2$(N))
- ~~std::stable_sort~~ => O(N*$\log_2^2$(N))

- std::minmax_element => O(N)
- std::nth_element => ~ O(N)
- std::partial_sort => O(N*$\log_2$(S))

std::nth_element(beg, mid, end)

- Reorders the range [beg, end) so that:
  - Value pointed to by mid does not change if we sort the range [beg, end)
  - Left from mid are values less or equal to the value pointed to by mid
  - Right from mid are values grater or equal to the value pointed to

4	0	3	1	2	5	9	8	7	6	@

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4	0	3	1	2	5	9	8	7	6	@

0	1	2	3	4	5	6	7	8	9	@

std::nth_element

Find 5 people with minimal balance

```
std::nth_element(v.begin(), v.begin() + 4, v.end());
```

Find 5 people with maximal balance

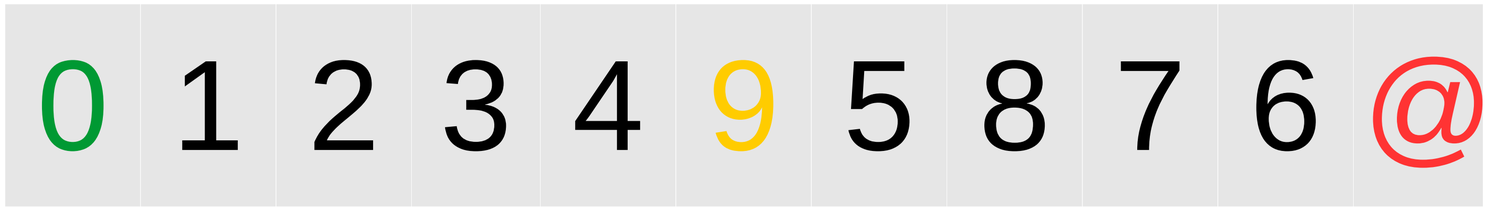
```
std::nth_element(v.begin(), v.begin() + 4, v.end(),
std::greater<>{});
```

Find the lucky 1001 caller

```
std::nth_element(v.begin(), v.begin() + 1000, v.end());
```

std::partial_sort(beg, mid, end)

- Reorders the range [beg, end) so that:
  - Range [beg, mid) won't change if we sort the whole [beg, end) range
  - Range [beg, mid) is sorted



std::partial_sort

Distribute 5 prizes according to minimal penalty points

```
std::partial_sort(v.begin(), v.begin() + 5, v.end());
```

Punish 5 latecomer scholars

```
std::partial_sort(v.begin(), v.begin() + 5, v.end(),
std::greater<>{});
```

std::minmax_element

Find richest and poorest client:

```
auto mm = std::minmax_element(v.begin(), v.end());
std::cout << *mm.first << ' ' << *mm.second << '\n';
```

The Question:

How to get a sorted list of 10 people with balance close to median?

(Effect same as if we sort everyone by balance and get 10 people from the middle).

HowTo?

```
auto it = v.begin() + v.size() / 2 - 5;
```

HowTo?

```
auto it = v.begin() + v.size() / 2 - 5;

const auto f = [](const auto& v1, const auto& v2) {

    return v1.balance() < v2.balance();

};
```

HowTo?

```
auto it = v.begin() + v.size() / 2 - 5;
const auto f = [](const auto& v1, const auto& v2) {
    return v1.balance() < v2.balance();
};

std::nth_element(v.begin(), it, v.end(), f);
```

HowTo?

```
auto it = v.begin() + v.size() / 2 - 5;
const auto f = [](const auto& v1, const auto& v2) {
    return v1.balance() < v2.balance();
};

std::nth_element(v.begin(), it, v.end(), f);
std::partial_sort(it + 1, it + 10, v.end(), f);
```

O(N*log(10)) vs O(N*log(N))

N	N*log(10) $N+(N/2-1)*\log_2(9)$	N*log(N)	N*log(N) – N*log(10)
10	33	33	0
16	53	64	11
512	1,701	4,608	2,907
16,384	54,426	229,376	174,950
524,288	1,741,647	9,961,472	8,219,825
16,777,216	55,732,705	402,653,184	346,920,479

How to force the compiler to solve the previous task?

???

```
template <class RandomAccessIterator>
void nth_element(RandomAccessIterator beg, RandomAccessIterator mid,
RandomAccessIterator end)
    [[expects: beg <= mid]]    [[expects: mid <= end]]
    [[ensures: ??? ]]
;
template <class RandomAccessIterator>
void partial_sort(RandomAccessIterator beg, RandomAccessIterator mid,
RandomAccessIterator end)
    [[expects: beg <= mid]]    [[expects: mid <= end]]
    [[ensures: ??? ]]
;
```

Contracts and algorithms

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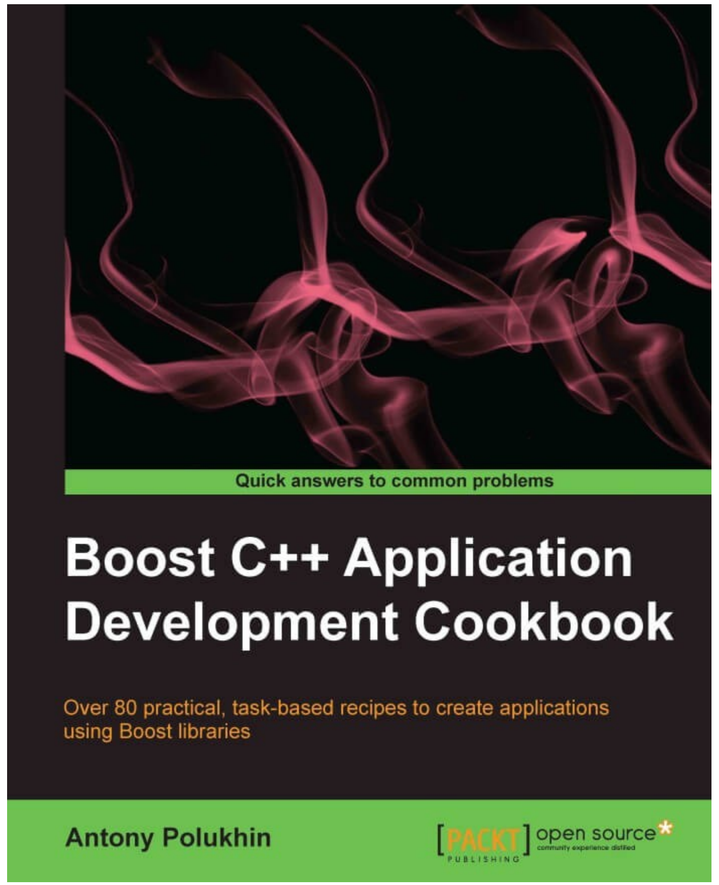
  - Unified syntax
  - Start of the long way to formal verification
  - Optimization hints
  - Problems
  - New horizons for research :-)

Thank you! Questions?

https://stdcpp.ru

C++

РГ21 C++ РОССИЯ



http://apolukhin.github.io/Boost-Cookbook