

Better Algorithm Intuition



Conor Hoekstra (he/him)



code_report



codereport



<https://rapids.ai>

#include

1. <https://github.com/codereport/Talks>

**“I’m not an expert,
I’m just a dude.”**

- Scott Schurr, CppCon 2015

constexpr: Applications

By Scott Schurr for Ripple Labs at CppCon September 2015



SCOTT SCHURR

constexpr:
Applications

About Me

- I'm a Senior Library Software Engineer for  NVIDIA.
 - Working on the  RAPIDS AI team (<http://rapids.ai>)
- I am a programming language enthusiast
- I've been coding in C++ for 5+ years*
- I love **auto** (AAA)
- I prefer **east const** (1 const west)
- I love algorithms and beautiful code
- I have a  YouTube channel





Conor Hoekstra

Algorithm Intuition

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```
template<class T>
using rev = reverse_iterator<T>;  
  
int trap(vector<int>& v) {
    vector u(v.size);
    auto it = max_element(v.begin(), v.end());
    inclusive_scan(it, v.end(), u.begin());
    inclusive_scan(v.begin(), it, u.end());
    return transform_reduce(u.begin(), u.end(),
                           std::plus<>(),
                           std::minus<>());
}
```



```
auto dangerous_teams(std::string const& s) -> bool {
    return s
        | views::group_by(std::equal_to{})
        | views::transform(ranges::distance)
        | ranges::any_of([](std::size_t s){
            return s >= 7;
        });
}
```

 Cppcon | 2019
The C++ Conference
cppcon.org Cppcon | 2019
The C++ Conference
cppcon.org Cppcon | 2019
The C++ Conference
cppcon.org

Conor Hoekstra

<https://brevzin.github.io/c%2B%2B/2019/08/22/ufcs-custom-extension/>

212

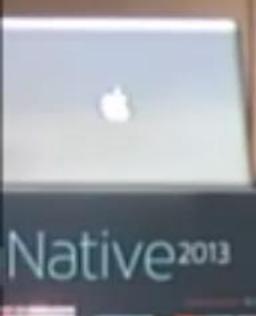
Algorithm Intuition
(part 2 of 2)

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Native²⁰¹³

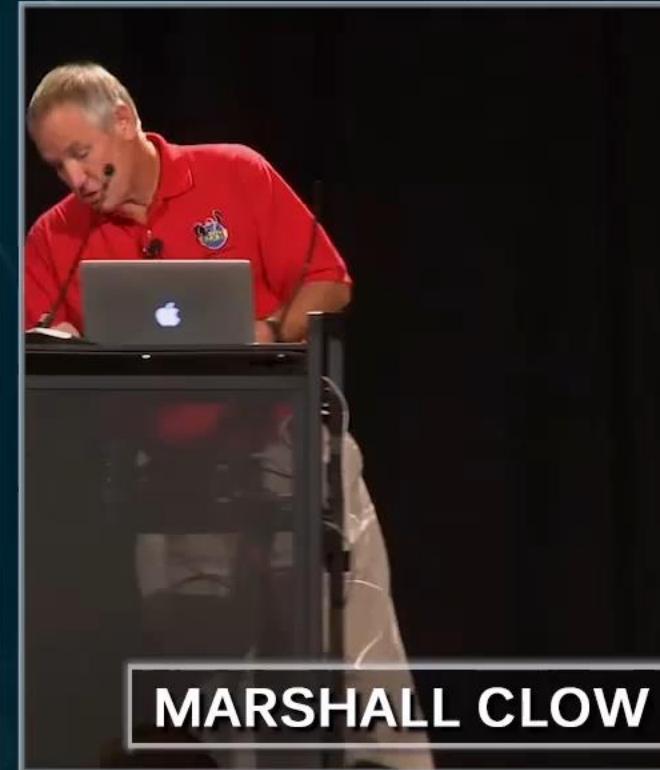
STL Algorithms - How to use them; how to write your own

Marshall Clow
Qualcomm, Inc.

CppCon 2016

mclow@qti.qualcomm.com

@mclow



MARSHALL CLOW

**STL Algorithms -
How you should use them;
how to write your own**

CppCon.org

“... and just as you can say, that would be a good use of a linked list, we don't have that **intuition** about **algorithms** yet, and we need to.”

- Kate Gregory



Goal

(once again)

- Get you excited about algorithms
- Learn a new algorithm
- Start to develop some **algorithm intuition**

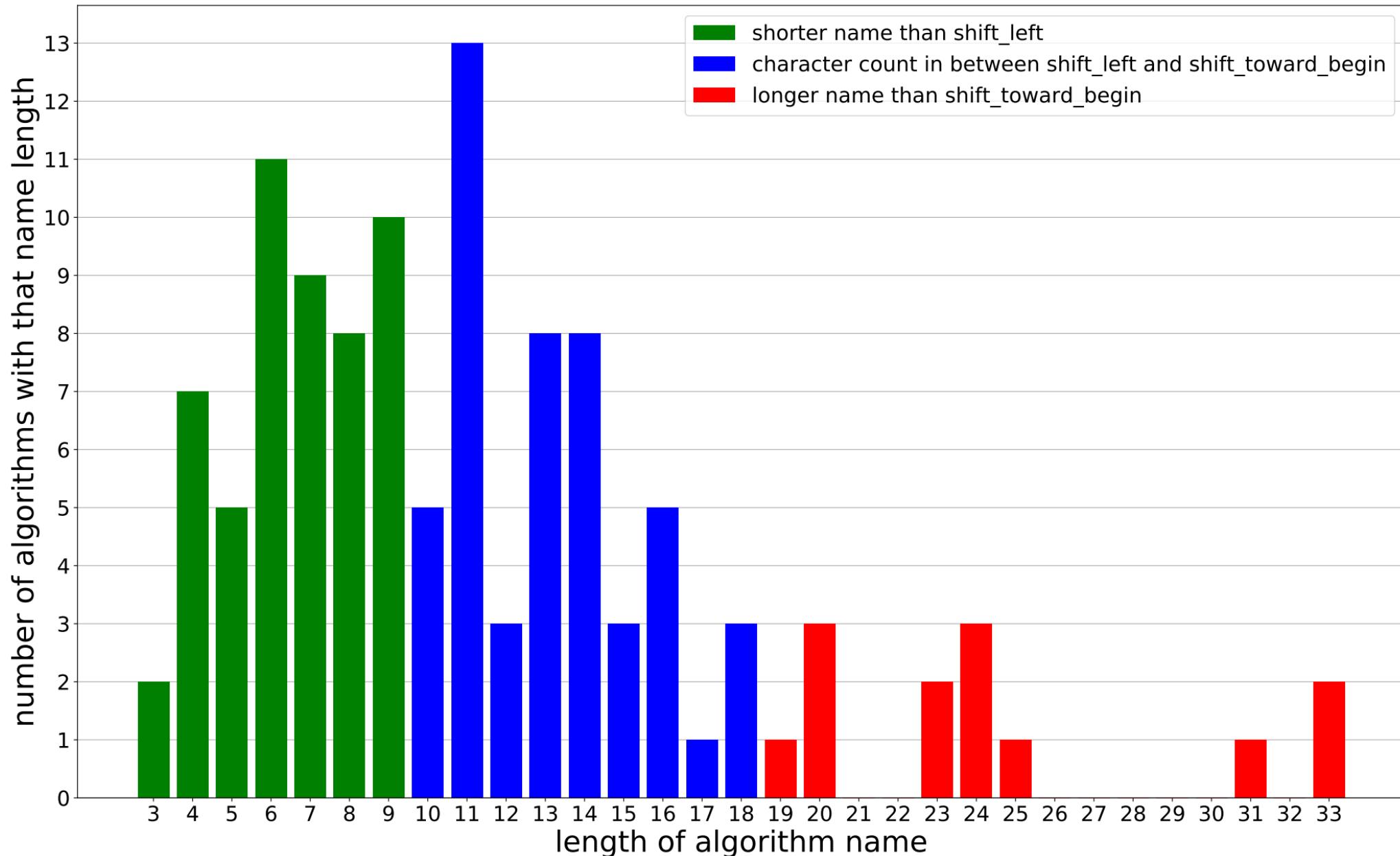
Prologue

<numeric> vs <algorithm>

Library	Pre-C++11	C++11	C++17	Grand Total
<algorithm>	66	19	3, -1	87*
<numeric>	4	1	6	11
<memory>	3	1	9	13
Grand Total	73	21	17*	111

Library	Pre-C++11	C++11	C++17	Grand Total
<algorithm>	66	19	3, -1	87*
<numeric>	4	1	6	11
<memory>	3	1	9	13
Grand Total	73	21	17*	111

Distribution of algorithm names character count



	7	bsearch	11	equal_range	15	is_sorted_until
3	7	copy_if	11	find_if_not	15	partition_point
3	7	destroy	11	lower_bound	15	replace_copy_if
	7	find_if	11	max_element		
	7	is_heap	11	min_element	16	next_permutation
	7	none_of	11	nth_element	16	prev_permutation
4	7	replace	11	partial_sum	16	set_intersection
4	7	reverse	11	remove_copy	16	stable_partition
4	7	shuffle	11	rotate_copy	16	transform_reduce
			11	stable_sort		
4	8	count_if	11	swap_ranges	17	partial_sort_copy
4	8	find_end	11	unique_copy		
4	8	for_each	11	upper_bound	18	uninitialized_copy
4	8	generate			18	uninitialized_fill
5	8	includes	12	partial_sort	18	uninitialized_move
5	8	mismatch	12	replace_copy		
5	8	pop_head	12	reverse_copy	19	adjacent_difference
5	8	search_n				
5	9	destroy_n	13	adjacent_find	20	uninitialized_copy_n
6	9	is_sorted	13	binary_search	20	uninitialized_fill_n
6	9	iter_swap	13	copy_backward	20	uninitialized_move_n
6	9	make_heap	13	find_first_of		
6	9	partition	13	inner_product	23	lexicographical_compare
6	9	push_heap	13	inplace_merge	23	uninitialized_construct
6	9	remove_if	13	is_heap_until		
6	9	set_union	13	move_backward	24	set_symmetric_difference
6	9	sort_heap	14	exclusive_scan	24	transform_exclusive_scan
6	9	transform	14	inclusive_scan	24	transform_inclusive_scan
			14	is_partitioned		
6	10	accumulate	14	is_permutation	25	uninitialized_construct_n
6	10	destroy_at	14	minmax_element		
6	10	for_each_n	14	partition_copy	31	uninitialized_default_construct
6	10	generate_n	14	remove_copy_if		
6	10	replace_if	14	set_difference	33	lexicographical_compare_three_way
					33	uninitialized_default_construct_n



Kate Gregory

Naming is Hard:
Let's Do Better

An <algorithm> story

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Kate Gregory

Naming is Hard:
Let's Do Better

An <algorithm> story

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Algorithm Love Club

0 Tweets



Algorithm Love Club

@algo_love_club

For those that want to join the Algorithm Love Club! Our leaders are [@SeanParent](#) and Kate Gregory ([@gregcons](#))!

@algo_love_club

Join the club on Twitter



#include

Chapter 1

LeetCode Level 1





344. Reverse String

Easy 908 581 Favorite Share

Write a function that reverses a string.



```
void reverseString(std::string& s) {  
    std::reverse(  
        std::begin(s),  
        std::end(s));  
}
```



[thrust::reverse](#)

344. Reverse String

Hot | Newest to Oldest | **Most Votes** | Most Posts | Recent Activity | Oldest to Newest



Simple C++ solution cpp

xz2210 created at: April 21, 2016 9:32 PM | Last Reply: yellomellofello August 28, 2019 8:25 PM



One Line C++ Code (with Help of STL) cpp

krrk2102 created at: April 22, 2016 12:53 PM | Last Reply: nicho December 12, 2018 8:53 AM



Share my C++ solution,very easy to understand cpp easy-understand

vdvvdd created at: April 23, 2016 7:21 PM | Last Reply: lidz March 16, 2019 10:48 PM



Easy C++ 2 Line Solution [beats 92%, 100%] 2 lines c++ clean-code + 4 more

Pooja0406 created at: September 4, 2019 12:44 AM | No replies yet.



[C++] One-Liner c++ cpp

KasraGhodsi created at: June 23, 2019 2:18 PM | No replies yet.



C++ solution without extra memory cpp

magiceye07 created at: May 25, 2019 2:12 PM | No replies yet.



Simple C++ code cpp solution solution-cpp

neelneelpurk created at: May 11, 2019 9:36 AM | No replies yet.

< Back

Simple C++ solution



★ 567

Last Edit: October 2, 2018 10:22 AM

54



```
class Solution {  
public:  
    string reverseString(string s) {  
        int i = 0, j = s.size() - 1;  
        while(i < j){  
            swap(s[i++], s[j--]);  
        }  
  
        return s;  
    }  
};
```

 ★ 479

April 23, 2016 7:21 PM

5

```
class Solution {  
public:  
    string reverseString(string s) {  
        int start = 0;  
        int end = s.length() - 1;  
        char ch = 0;  
  
        for (; start < end; start++, end--) {  
            ch = s[start];  
            s[start] = s[end];  
            s[end] = ch;  
        }  
  
        return s;  
    }  
};
```

< Back

Easy C++ 2 Line Solution [beats 92%, 100%]



★ 83

Last Edit: September 4, 2019 12:44 AM

0

Runtime: 44 ms, faster than 92.12% of C++ online submissions for Reverse String.



Memory Usage: 15.2 MB, less than 96.34% of C++ online submissions for Reverse String.

```
void reverseString(vector<char>& s) {  
  
    for(int start=0, end = s.size()-1; start < end; start++, end--)  
        swap(s[start], s[end]);  
}
```

< Back

[C++] One-Liner



★ 74

June 23, 2019 2:18 PM

0



< Back

One Line C++ Code (with Help of STL)



★ 8

April 22, 2016 12:53 PM

8





709. To Lower Case

Easy

341

1188

Favorite

Share

Implement function `ToLowerCase()` that has a string parameter `str`, and returns the same string in lowercase.



```
std::string toLowerCase(string s) {  
    std::transform(  
        std::begin(s),  
        std::end(s),  
        std::begin(s),  
        ::tolower);  
  
    return s;  
}
```



[thrust::transform](#)



```
toLowerCase :: String -> String  
toLowerCase = map toLower
```



905. Sort Array By Parity

Easy 586 62 Favorite Share

Given an array `A` of non-negative integers, return an array consisting of all the even elements of `A`, followed by all the odd elements of `A`.

You may return any answer array that satisfies this condition.



```
auto sortArrayByParity(vector<int>& A) {  
    std::partition(  
        std::begin(A),  
        std::end(A),  
        [](auto e) {  
            return e % 2 == 0;  
        });  
  
    return A;  
}
```



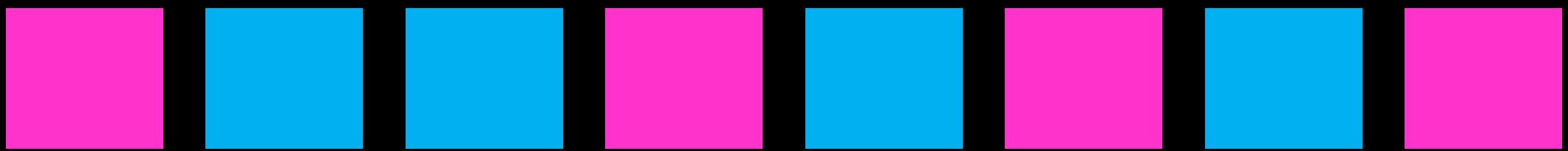
[thrust::partition](#)



“two finger method”



@ivan_cukic





[1,2,3,4,5,6]
([1,3,5],[2,4,6])
[1,3,5,2,4,6]

```
sortArrayByParity :: [Int] -> [Int]
sortArrayByParity = uncurry (++)
| | | | |
| | | | . partition odd
```



283. Move Zeroes

Easy

2463

90

Favorite

Share

Given an array `nums`, write a function to move all `0`'s to the end of it while maintaining the relative order of the non-zero elements.



```
void moveZeroes(vector<int>& nums) {  
    std::stable_partition(  
        std::begin(nums),  
        std::end(nums),  
        [] (auto e) {  
            return e != 0;  
        });  
}
```



[thrust::stable_partition](#)



[1,0,2,0,3,0]
([1,2,3],[0,0,0])
[1,2,3,0,0,0]

```
moveZeroes :: [Int] -> [Int]
moveZeroes = uncurry (++)
| | |
| . partition (/=0)
```



973. K Closest Points to Origin

Medium

782

75

Favorite

Share

We have a list of `points` on the plane. Find the `K` closest points to the origin $(0, 0)$.

(Here, the distance between two points on a plane is the Euclidean distance.)

You may return the answer in any order. The answer is guaranteed to be unique (except for the order that it is in.)



```
vector<vector<int>> kClosest(
    vector<vector<int>>& points, int K) {

    std::sort(
        std::begin(points),
        std::end(points),
        [] (auto const& a, auto const& b) {
            return sqrt(a[0] * a[0] + a[1] * a[1]) <
                   sqrt(b[0] * b[0] + b[1] * b[1]);
        });

    return vector(
        std::begin(points),
        std::begin(points) + K);
}
```



[thrust::sort](#)



```
vector<vector<int>> kClosest(
    vector<vector<int>>& points, int K) {

    std::sort(
        std::begin(points),
        std::end(points),
        [] (auto const& a, auto const& b) {
            return (a[0] * a[0] + a[1] * a[1]) <
                (b[0] * b[0] + b[1] * b[1]);
        });

    return vector(
        std::begin(points),
        std::begin(points) + K);
}
```



[thrust::sort](#)



```
vector<vector<int>> kClosest(
    vector<vector<int>>& points, int K) {

    std::partial_sort(
        std::begin(points),
        std::begin(points) + K,
        std::end(points),
        [] (auto const& a, auto const& b) {
            return (a[0] * a[0] + a[1] * a[1]) <
                (b[0] * b[0] + b[1] * b[1]);
        });

    return vector(
        std::begin(points),
        std::begin(points) + K);
}
```



```
vector<vector<int>> kClosest(
    vector<vector<int>>& points, int K) {

    std::nth_element(
        std::begin(points),
        std::begin(points) + K,
        std::end(points),
        [] (auto const& a, auto const& b) {
            return (a[0] * a[0] + a[1] * a[1]) <
                (b[0] * b[0] + b[1] * b[1]);
        });

    return vector(
        std::begin(points),
        std::begin(points) + K);
}
```



`std::sort`



`std::partial_sort`



`std::nth_element`



Kate Gregory

Naming is Hard:
Let's Do Better

An <algorithm> story

- sort
- partial_sort

1 5 4 2 9 7

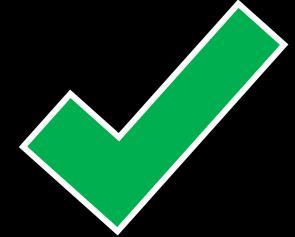
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partial_sort_copy

top_n



nth_element_copy

top_n



`set`

`unordered_set`



`nth_element_copy`

`top_n`

`partial_sort_copy`

`top_n_sorted`



reverse

stable_partition

transform

nth_element

for_each

sort

partition

partial_sort



std::swap ->
std::move

`reverse`

`stable_partition`

`transform`

`nth_element`

`for_each`

`sort`

`partition`

`partial_sort`



std::swap ->
std::move

reverse

stable_partition

transform

nth_element

for_each

sort

partition

partial_sort



move

swap

stable_partition



Chapter 2

LeetCode Level 2





977. Squares of a Sorted Array

Easy

543

57

Favorite

Share

Given an array of integers A sorted in non-decreasing order, return an array of the squares of each number, also in sorted non-decreasing order.

Note:

1. $1 \leq A.length \leq 10000$
2. $-10000 \leq A[i] \leq 10000$
3. A is sorted in non-decreasing order.



```
vector<int> sortedSquares(vector<int>& A) {  
    std::transform(  
        std::begin(A),  
        std::end(A),  
        std::begin(A),  
        [] (auto e) {  
            return e * e;  
        });  
  
    std::sort(  
        std::begin(A),  
        std::end(A));  
  
    return A;  
}
```



[thrust::transform](#) [thrust::sort](#)



```
vector<int> sortedSquares(vector<int>& A) {
    transform(begin(A), end(A), begin(A),
              [] (auto e) { return e * e; });
    sort(begin(A), end(A));
    return A;
}
```



[thrust::transform](#) [thrust::sort](#)



20 Ranges

<https://godbolt.org/z/4wQbNY>

```
namespace rv = ranges::views;
namespace ra = ranges::actions;

auto sortedSquares(std::vector<int> A) {
    return A
        | rv::all
        | ra::transform([] (int e) { return e * e; })
        | ra::sort
        | ranges::to<std::vector<int>>;
}
```



[thrust::transform](#) [thrust::sort](#)



[1,3,2,5,4]
[1,9,4,25,16]
[1,4,9,16,25]

```
square :: Int -> Int  
square n = n * n
```

```
sortedSquares :: [Int] -> [Int]  
sortedSquares = sort . map square
```



961. N-Repeated Element in Size 2N Array

Easy 271 167 Favorite Share

In a array A of size $2N$, there are $N+1$ unique elements, and exactly one of these elements is repeated N times.

Return the element repeated N times.



961. Element Repeated Once

Easy 271 167 Favorite Share

In an array A of size N , there are $N - 1$ unique values (therefore exactly one of those values appears twice).

Return the value that is repeated 2 times.



```
int repeatedNTimes(vector<int>& A) {  
    std::sort(  
        std::begin(A),  
        std::end(A));  
  
    return *std::adjacent_find(  
        std::cbegin(A),  
        std::cend(A));  
}
```



[thrust::sort](#)



```
[2,1,2,2,3,4]
[(1,1),(2,3),(3,1),(4,1)]
[(2,3)]
(2,3)
2
```

```
import Data.List.Unique (count)

repeatedNTimes :: [Int] -> Int
repeatedNTimes = fst
  . head
  . filter ((>1) . snd)
  . count x
```



33. Search in Rotated Sorted Array

Medium

3093

368

Favorite

Share

Suppose an array sorted in ascending order is rotated at some pivot unknown to you beforehand.

(i.e., `[0,1,2,4,5,6,7]` might become `[4,5,6,7,0,1,2]`).

If found in the array return `true`, otherwise return `false`.

You may assume no duplicate exists in the array.

Your algorithm's runtime complexity must be in the order of $O(\log n)$.



```
bool search(vector<int>& nums, int target) {
    auto f = std::cbegin(nums);
    auto l = std::cend(nums);
    auto p = std::is_sorted_until(f, l);
    return target >= *f ? std::binary_search(f, p, target)
                         : std::binary_search(p, l, target);
}
```



[thrust::is_sorted_until](#) [thrust::binary_search](#)



```
bool search(vector<int>& nums, int target) {
    auto f = std::cbegin(nums);
    auto l = std::cend(nums);
    auto p = std::partition_point(f, l,
        [x = *f] (auto const& e) {
            return e >= x;
        });
    return target >= *f ? std::binary_search(f, p, target)
        : std::binary_search(p, l, target);
}
```



[thrust::partition_point](#) [thrust::binary_search](#)



```
bool search(vector<int>& nums, int target) {
    auto f = std::cbegin(nums);
    auto l = std::cend(nums);
    auto p = std::partition_point(f, l,
        std::bind(std::greater_equal{}, _1, *f));
    return target >= *f ? std::binary_search(f, p, target)
                         : std::binary_search(p, l, target);
}
```



[thrust::partition_point](#) [thrust::binary_search](#)

Chapter 3

Haskell Engineering



The Four Horseshoers of the



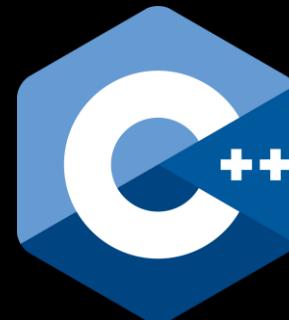
@incomputable



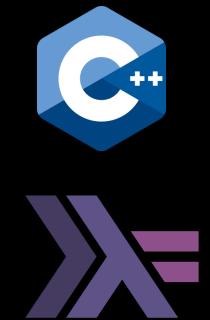
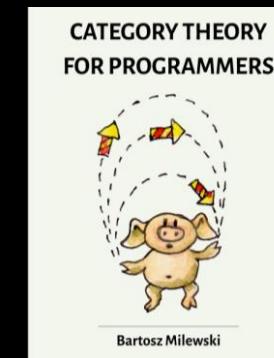
@WalterBright



@ericniebler



@BartoszMilewski





@odinthenerd

”...contemporary programming languages are grossly inferior. The enormous, but not strong,...

Inherent constraints at the most basic level cause them to be both slow and weak...

their intuitive hand-at-a-time style of programming inherited from their common ancestor --the von Neumann computer, [...] and their lack of useful mathematical properties for reasoning about programs.”

Auto-Intern GmbH

13

Is this good?

Can Programming Be Liberated from the von Neumann Style?
A Functional Style and Its Algebra of Programs

-- John Backus 1978



Odin Holmes

Tacit DSL All the Things

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“As soon as they start dabbling in
functional programming,
they never come back.

- Odin Holmes



@odinthenerd

C++Now 2019: Odin Holmes “Tacit DSL All the Things”

https://github.com/graninas/cpp_functional_programming

- Bartosz Milewski talks
 - Functional Patterns in C++, 1. Functors, 2012
 - Functional Patterns in C++, 2. Currying, Applicative, 2012
 - Functional Patterns in C++, 3. Async API, Monoid, Monad, 2012
 - Compile-Time/Run-Time Functional Programming in C++, Bartosz Milewski, Eric Niebler, BoostCon, 2012
 - Haskell -- The Pseudocode Language for C++ Template Metaprogramming (Part 1), BoostCon, 2013
 - Haskell -- The Pseudocode Language for C++ Template Metaprogramming (Part 2), BoostCon, 2013
 - Re-discovering monads in C++, C++ User Group Novosibirsk, 2014
 - Functional techniques in C++, CDays14, 2014
 - Categories for the Working C++ Programmer, C++ Russia, 2015
 - Monads for C++, itCppCon17, 2017

“Even if you program in C++, it is a good idea to learn some Haskell.”



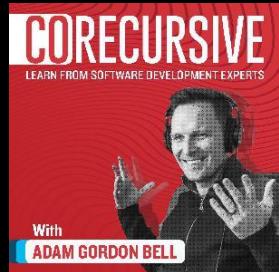
- Bartosz Milewski
@BartoszMilewski



“... if you solve your problem first in Haskell
and then you translate it into C++ you will
probably get better quality code.”



- Bartosz Milewski
@BartoszMilewski





42. Trapping Rain Water

Hard 3387 61 Favorite Share

Given n non-negative integers representing an elevation map where the width of each bar is 1, compute how much water it is able to trap after raining.



The above elevation map is represented by array [0,1,0,2,1,0,1,3,2,1,2,1]. In this case, 6 units of rain water (blue section) are being trapped. **Thanks Marcos** for contributing this image!



```
template<class T>
using rev = reverse_iterator<T>;\n\nint trap(vector<int>& v) {\n    vector u(v.size(), 0);\n    auto it = max_element(begin(v), end(v));\n    inclusive_scan(begin(v), next(it), begin(u), ufo::max{});\n    inclusive_scan(rbegin(v), rev(it), rbegin(u), ufo::max{});\n    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,\n        std::plus<>(),\n        std::minus<>());\n}
```



[thrust::inclusive_scan](#) [thrust::transform_reduce](#) [thrust::max_element](#)



```
trappingRain :: [Int] -> Int
trappingRain xs =
    where
```



```
trappingRain :: [Int] -> Int
trappingRain xs = sum $ zipWith (-) ys xs
  where m      = maximum xs
        i      = length $ takeWhile (/=m) xs
        a      = take i xs
        b      = drop i xs
        ys    = scanl1 max a ++ scanr1 max b
```



```
trappingRain :: [Int] -> Int
trappingRain xs = sum $ zipWith (-) ys xs
  where m      = maximum xs
        i      = length $ takeWhile (/=m) xs
        (a,b) = splitAt i xs
        ys    = scanl1 max a ++ scanr1 max b
```



```
trappingRain :: [Int] -> Int
trappingRain xs = sum $ zipWith (-) ys xs
  where m      = maximum xs
        | (a,b) = break (==m) xs
        | ys    = scanl1 max a ++ scanr1 max b
```



```
trappingRain :: [Int] -> Int
trappingRain xs = sum $ zipWith (-) ys xs
  where m      = maximum xs
        (a,b) = break (==m) xs
        ys    = scanl1 max a ++ scanr1 max b
```

```
toLowerCase :: String -> String
toLowerCase = map toLower
```

transform_reduce

reduce

transform

?

max_element

inclusive_scan



```
zipWith :: (a -> b -> c) -> [a] -> [b] -> [c]
map   :: (a -> b) -> [a] -> [b]
```



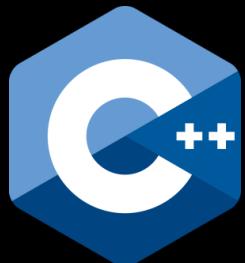
```
zipWith :: (a -> b -> c) -> [a] -> [b] -> [c]
map      :: (a -> b)        -> [a] -> [b]
```



```
zipWith :: (a -> b -> c) -> [a] -> [b] -> [c]
map      :: (a -> b)        -> [a]           -> [b]
```



```
zipWith :: (a -> b -> c) -> [a] -> [b] -> [c]
map      :: (a -> c)       -> [a]           -> [c]
```



std::transform



Chapter 4

LeetCode Level 3



Quickly mention

find_if → **lower_bound**

find_if → **upper_bound**

```
// Next, check if the panel has moved to the other side of another panel.  
  
auto p = find_if(begin(expanded_panels_), end(expanded_panels_),  
    [&](const ref_ptr<Panel>& e){ return center_x <= e->cur_panel_center(); });  
  
// Fix this code - panel is the panel found above.  
  
if (panel != fixed_panel) {  
    // If it has, then we reorder the panels.  
    ref_ptr<Panel> ref = expanded_panels_[fixed_index];  
    expanded_panels_.erase(expanded_panels_.begin() + fixed_index);  
    expanded_panels_.insert(expanded_panels_.begin() + i, ref);  
}
```

Quickly mention

find_if → **lower_bound**

find_if → **upper_bound**



917. Reverse Only Letters

Easy

321

30

Favorite

Share

Given a string `s`, return the "reversed" string where all characters that are not a letter stay in the same place, and all letters reverse their positions.

1ab2cd -> 1dc2ba

How many STL algorithms will it take to solve?

1

2

3

4



```
string reverseOnlyLetters(string S) {  
    std::string letters;  
  
    std::copy_if(  
        std::begin(S),  
        std::end(S),  
        std::back_inserter(letters),  
        ::isalpha);  
  
    std::reverse(  
        std::begin(letters),  
        std::end(letters));  
  
    std::transform(  
        std::begin(S),  
        std::end(S),  
        std::begin(S),  
        [c = std::cbegin(letters)] (auto e) mutable {  
            return isalpha(e) ? *c++ : e;  
       });  
  
    return S;  
}
```

[transform](#) [reverse](#) [copy_if](#)





```
string reverseOnlyLetters(string S) {  
    std::string letters;  
  
    std::copy_if(  
        std::crbegin(S),  
        std::crend(S),  
        std::back_inserter(letters),  
        ::isalpha);  
  
    std::transform(  
        std::begin(S),  
        std::end(S),  
        std::begin(S),  
        [c = std::cbegin(letters)] (auto e) mutable {  
            return isalpha(e) ? *c++ : e;  
        });  
  
    return S;  
}
```



[transform](#) [copy_if](#)



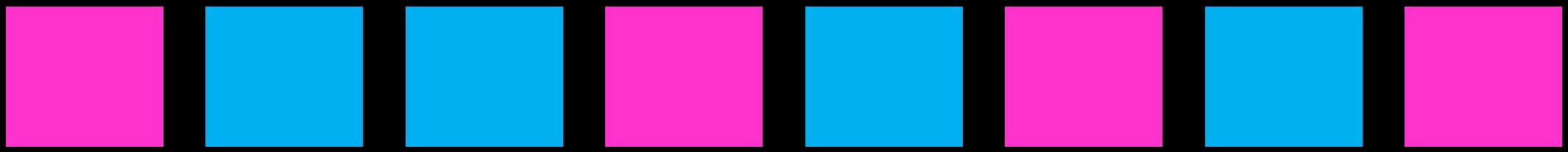
```
string reverseOnlyLetters(string S) {  
    std::reverse_if(  
        std::begin(S),  
        std::end(S),  
        ::isalpha);  
  
    return S;  
}
```

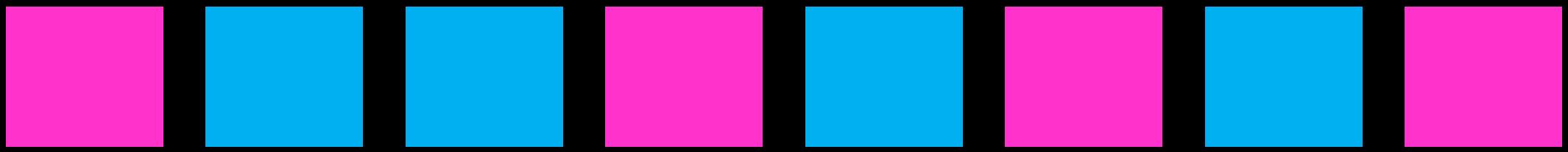


```
template <class B, class P>
void reverse_if(B first, B last, P pred) {
    while (first != last) {
        while (!pred(*first)) ++first;
        while (!pred(*last)) --last;
        iter_swap(first++, last++);
    }
}
```



```
template <class B, class P>
void reverse_if(B f, B l, P pred) {
    while (f != l) {
        while (!pred(*f)) { ++f; if (f == l) goto done; }
        while (!pred(*l)) { --l; if (f == l) goto done; }
        iter_swap(f++, l);
        if (f == l) break;
        ++l;
    }
done: ;
}
```







```
std::string reverseOnlyLetters(std::string S) {  
    std::partition(  
        std::begin(S),  
        std::end(S),  
        [b = true] (auto e) mutable {  
            if (isalpha(e)) b = !b;  
            return b;  
        });  
  
    return S;  
}
```



[thrust::partition](#)

How many STL algorithms will it take to solve?

1

2

3

4

Chapter 5

The Sean Parent Game





`std::is_sorted`



`std::is_sorted_until`



```
template<class _FwdIt,
         class _Pr>
_NODISCARD inline bool is_sorted(_FwdIt _First, _FwdIt _Last, _Pr _Pred)
{   // test if range is ordered by predicate
    _Adl_verify_range(_First, _Last);
    const auto _UFirst = _Get_unwrapped(_First);
    const auto _ULast = _Get_unwrapped(_Last);
    return (_STD is_sorted_until(_UFirst, _ULast, _Pass_fn(_Pred)) == _ULast);
}
```



[thrust::is_sorted](#) [thrust::is_sorted_until](#)



`std::is_sorted`



`std::is_sorted_until`



`std::adjacent_find`



```
template<class _FwdIt,
         class _Pr>
_NODISCARD inline _FwdIt is_sorted_until(const _FwdIt _First, _FwdIt _Last, _Pr _Pred)
{   // find extent of range that is ordered by predicate
    _Adl_verify_range(_First, _Last);
    auto _UFirst = _Get_unwrapped(_First);
    auto _ULast = _Get_unwrapped(_Last);
    if (_UFirst != _ULast)
    {
        for (auto _UNext = _UFirst; ++_UNext != _ULast; ++_UFirst)
        {
            if (_DEBUG_LT_PRED(_Pred, *_UNext, *_UFirst))
            {
                _ULast = _UNext;
                break;
            }
        }
    }

    _Seek_wrapped(_Last, _ULast);
    return (_Last);
}
```



```
template<class _FwdIt,
         class _Pr>
_NODISCARD inline _FwdIt adjacent_find(const _FwdIt _First, _FwdIt _Last, _Pr _Pred)
{   // find first satisfying _Pred with successor
    _Adl_verify_range(_First, _Last);
    auto _UFirst = _Get_unwrapped(_First);
    auto _ULast = _Get_unwrapped(_Last);
    if (_UFirst != _ULast)
    {
        for (auto _UNext = _UFirst; ++_UNext != _ULast; _UFirst = _UNext)
        {
            if (_Pred(*_UFirst, *_UNext))
            {
                _ULast = _UFirst;
                break;
            }
        }
    }

    _Seek_wrapped(_Last, _ULast);
    return (_Last);
}
```



```
1 template<class _FwdIt,
2      class _Pr>
3     _NODISCARD inline _FwdIt adjacent_find(const
4     _FwdIt _First, _FwdIt _Last, _Pr _Pred)
5     { // find first satisfying _Pred with successor
6         _Adl_verify_range(_First, _Last);
7         auto _UFirst = _Get_unwrapped(_First);
8         auto _ULast = _Get_unwrapped(_Last);
9         if (_UFirst != _ULast)
10            {
11                for (auto _UNext = _UFirst; ++_UNext != _ULast; _UFirst = _UNext)
12                    {
13                        if (_Pred(*_UFirst, *_UNext))
14                            {
15                                _ULast = _UFirst;
16                                break;
17                            }
18            }
19
20         _Seek_wrapped(_Last, _ULast);
21         return (_Last);
22     }
```

```
1 template<class _FwdIt,
2      class _Pr>
3     _NODISCARD inline _FwdIt is_sorted_until(const
4     _FwdIt _First, _FwdIt _Last, _Pr _Pred)
5     { // find extent of range that is ordered by predicate
6         _Adl_verify_range(_First, _Last);
7         auto _UFirst = _Get_unwrapped(_First);
8         auto _ULast = _Get_unwrapped(_Last);
9         if (_UFirst != _ULast)
10            {
11                for (auto _UNext = _UFirst; ++_UNext != _ULast; ++_UFirst)
12                    {
13                        if (_DEBUG_LT_PRED(_Pred, *_UNext, *_UFirst))
14                            {
15                                _ULast = _UNext;
16                                break;
17                            }
18            }
19
20         _Seek_wrapped(_Last, _ULast);
21         return (_Last);
22     }
```



```
#include <boost/hana/functional/flip.hpp>

template<class F, class P>
F is_sorted_until(F first, F last, P pred) {
    return std::adjacent_find(
        first,
        last,
        boost::hana::flip(pred));
}
```





`std::is_sorted`



`std::is_sorted_until`



`std::adjacent_find`



`std::is_sorted`



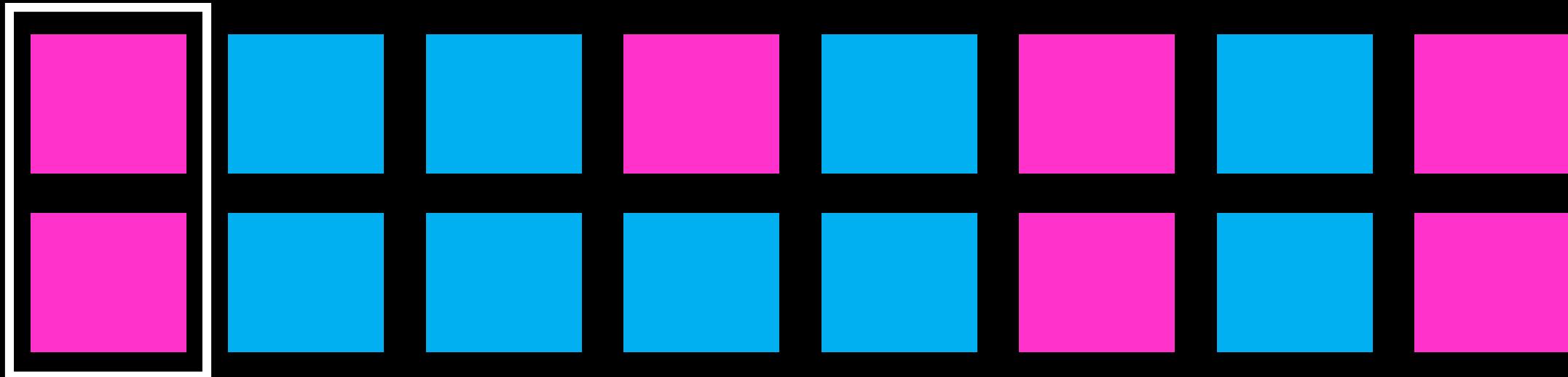
`std::is_sorted_until`



`std::adjacent_find`



`std::mismatch`





```
template <class I, class P>
I adjacent_find(I first, I last, P pred) {
    return std::mismatch(
        first,
        std::prev(last),
        std::next(first),
        [pred] (auto const& a, auto const& b) {
            return !pred(a, b);
        }).first;
}
```



```
template <class I, class P>
I adjacent_find(I first, I last, P pred) {
    return std::mismatch(
        first,
        std::prev(last),
        std::next(first),
        std::not_fn(pred)).first;
}
```





zip_find

transform_find



zip_find

```
template <class F, class F2, class P>
auto mismatch(F first, F last, F2 first2, P pred) {
    std::zip_find(
        first,
        last,
        first2,
        std::not_fn(pred));
}
```



adjacent_find

```
template <class I, class P>
I adjacent_find(I first, I last, P pred) {
    return zip_find(
        first,
        std::prev(last),
        std::next(first),
        pred).first;
}
```



mismatch -> **zip_find**

transform -> **zip_with**

inner_product -> **zip_reduce**

transform_reduce -> **zip_reduce**

equal -> **zip_reduce(logical_and, equal_to)**



```
template<class _InIt1,
         class _InIt2,
         class _Pr> inline
bool _Equal_unchecked1(_InIt1 _First1, const _InIt1 _Last1,
                      _InIt2 _First2, _Pr _Pred, false_type)
{   // compare [_First1, _Last1) to [_First2, ...) using _Pred,
for (; _First1 != _Last1; ++_First1, (void)++_First2)
{
    if (!_Pred(*_First1, *_First2))
    {
        return (false);
    }
}

return (true);
}
```



```
template <class InputIterator1,
          class InputIterator2,
          class BinaryPredicate>
inline bool equal(InputIterator1 first1,
                  InputIterator1 last1,
                  InputIterator2 first2,
                  BinaryPredicate binary_pred) {
    return mismatch(
        first1,
        last1,
        first2,
        binary_pred).first == last1;
}
```



<http://stepanovpapers.com/butler.hpl.hp/stl/stl/ALGOBASE.H>

```
template <class InputIterator1,
          class InputIterator2,
          class BinaryPredicate>
inline bool equal(InputIterator1 first1,
                  InputIterator1 last1,
                  InputIterator2 first2,
                  BinaryPredicate binary_pred) {
    return mismatch(
        first1,
        last1,
        first2,
        binary_pred).first == last1;
}
```





<http://stepanovpapers.com/butler.hpl.hp/stl/stl/ALGOBASE.H>

```
template <class InputIterator1, class InputIterator2, class BinaryPredicate>
inline bool equal(InputIterator1 first1, InputIterator1 last1,
                  InputIterator2 first2, BinaryPredicate binary_pred) {
    return mismatch(first1, last1, first2, binary_pred).first == last1;
}
```



mismatch -> **zip_find**

transform -> **zip_with**

inner_product -> **zip_reduce**

transform_reduce -> **zip_reduce**

equal -> **zip_reduce(logical_and, equal_to)**

equal -> **mismatch() == end()**

includes, merge, search, set_*, swap_range



mismatch -> **zip_find**

adjacent_difference -> **adjacent_transform**



reverse
transform
partition
stable_partition
sort
partial_sort
nth_element
remove_if

unique
for_each
copy
adjacent_find
partial_sort_copy
partition_point
binary_search
prev_permutation

is_sorted
is_sorted_until
find_if
equal_range
lower_bound
copy_if
mismatch
equal

Conclusion

Chapter 1:

sort | partial_sort | nth_element
remove_if | stable_partition

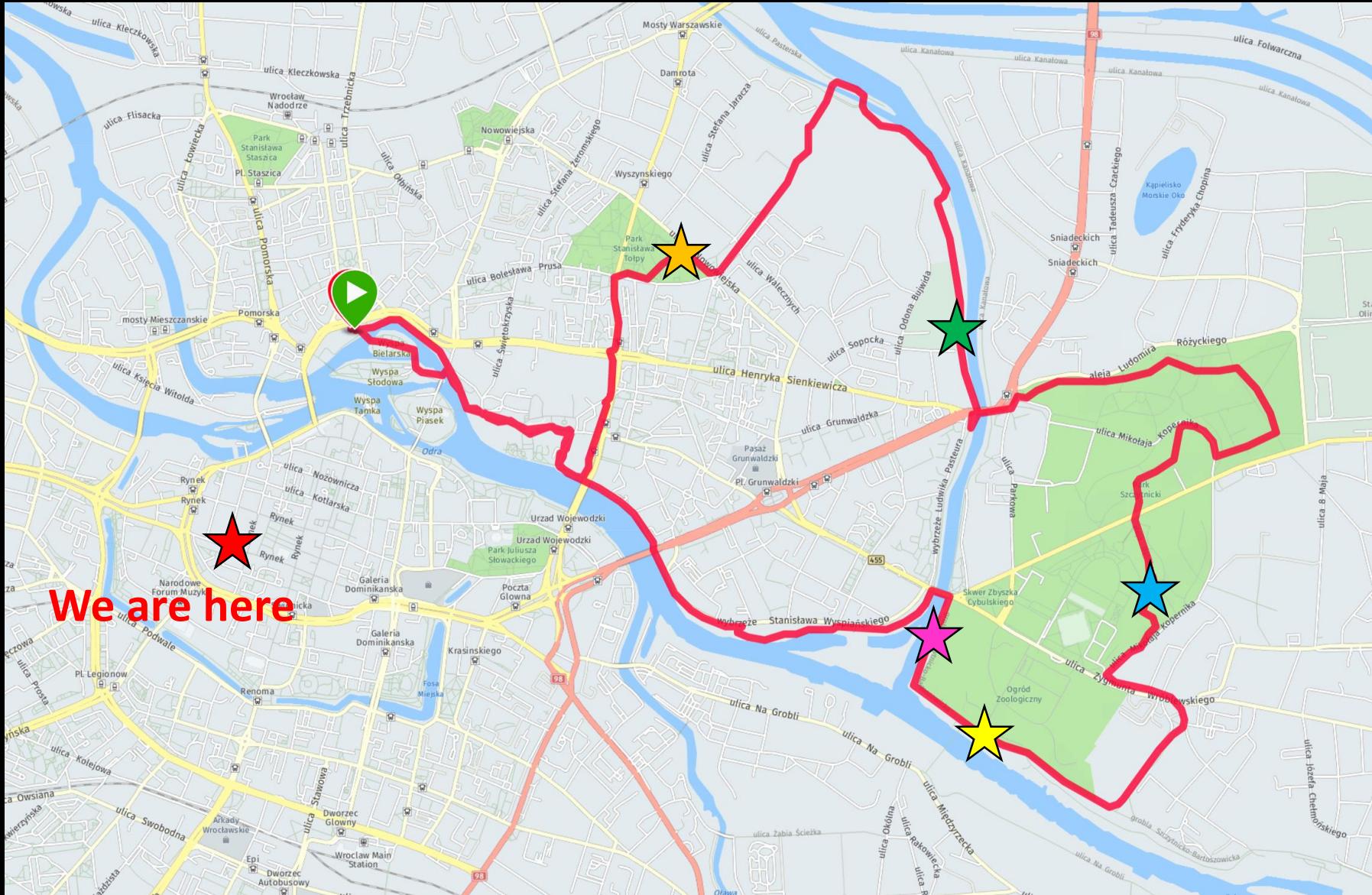
Chapter 2: is_sorted_until | partition_point (... is log n)

Chapter 3: transform is both zipWith and map

Chapter 4:

find_if | lower_bound / upper_bound
partition | reverse_if

Chapter 5: is_sorted | is_sorted_until | adjacent_find | mismatch





Thank you!

<https://github.com/codereport/Talks/>

Conor Hoekstra

 code_report

 codereport



Questions?

<https://github.com/codereport/Talks/>

Conor Hoekstra

 code_report

 codereport



Bonus Slides



1051. Height Checker

Easy

90

708

Favorite

Share

Students are asked to stand in non-decreasing order of heights for an annual photo.

Return the minimum number of students not standing in the right positions. (This is the number of students that must move in order for all students to be standing in non-decreasing order of height.)



```
int heightChecker(vector<int>& heights) {  
    std::vector<int> h_copy(heights.size());  
  
    std::partial_sort_copy(  
        std::begin(heights),  
        std::end(heights),  
        std::begin(h_copy),  
        std::end(h_copy));  
  
    return std::inner_product(  
        std::begin(heights),  
        std::end(heights),  
        std::begin(h_copy),  
        0,  
        std::plus{},  
        std::not_equal_to{});  
}
```



[thrust::inner_product](#)



[3,2,1,4]
[(3,1),(2,2),(1,3),(4,4)]
[2,0,-2,0]
[0,0]
2

```
heightChecker :: [Int] -> Int
heightChecker = length
| | | | . filter (==0)
| | | | . (zipWith (-) <*> sort)
```



1053. Previous Permutation With One Swap

Medium

62

161

Favorite

Share

Given an array `A` of positive integers (not necessarily distinct), return the lexicographically largest permutation that is smaller than `A`, that can be **made with one swap** (A swap exchanges the positions of two numbers `A[i]` and `A[j]`). If it cannot be done, then return the same array.

`[3,2,1]` -> `[3,1,2]`

`[1,1,5]` -> `[1,1,5]`

`[1,9,4,6,7]` -> `[1,7,4,6,9]`

How many STL algorithms will it take to solve?

1

2

3

4



[1,1,5]



```
vector<int> prevPermOpt1(vector<int>& A) {  
    prev_permutation(A.begin(), A.end());  
    return A;  
}
```



[1,9,4,6,7]

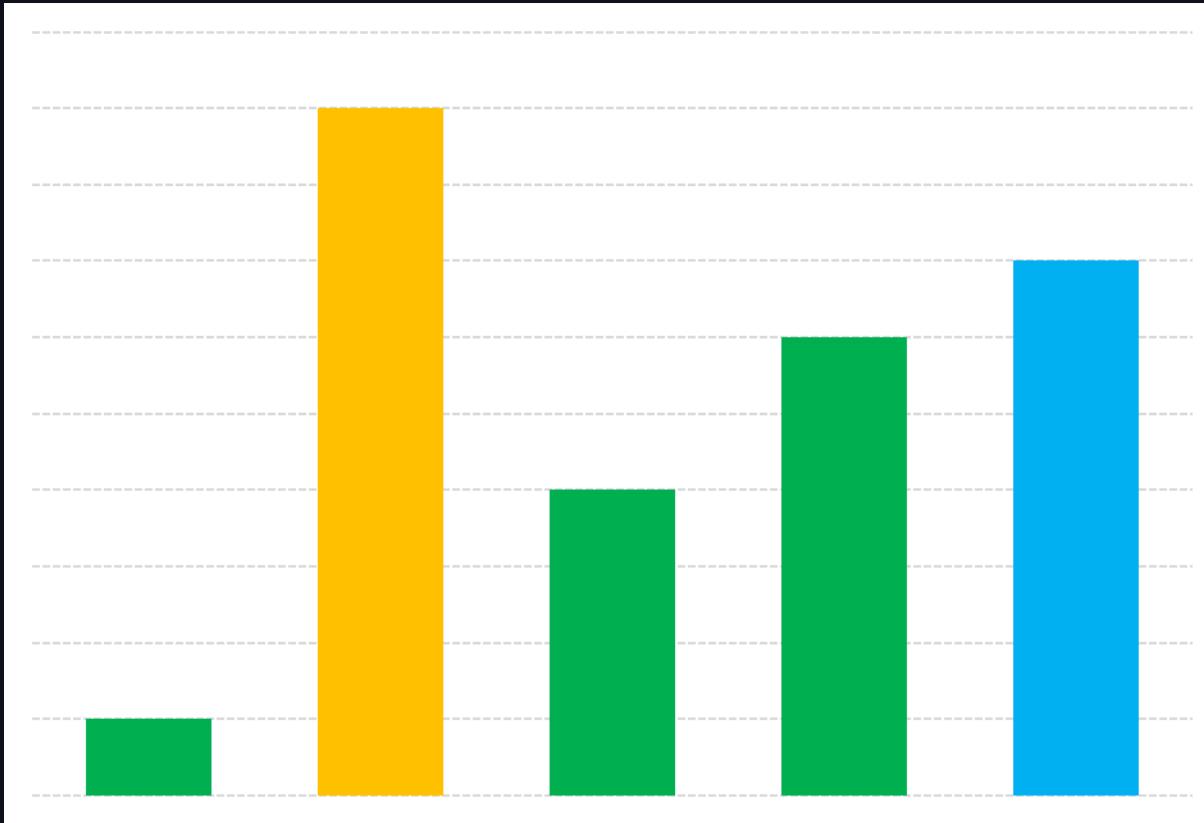


[1,7,4,6,9]

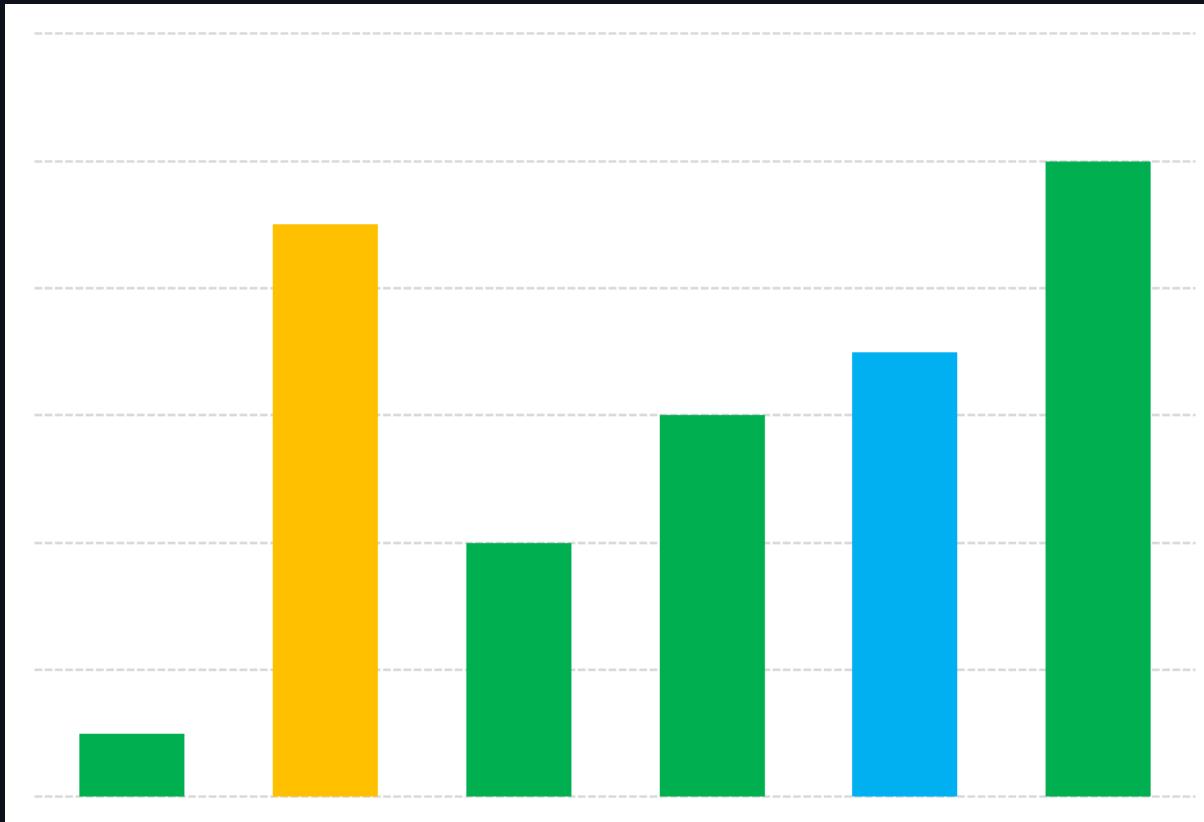
```
vector<int> prevPermOpt1(vector<int>& A) {  
    if (!is_sorted(A.begin(), A.end()))  
        prev_permutation(A.begin(), A.end());  
    return A;  
}
```



[thrust::is_sorted](#)



[1,9,4,6,7]



[1,9,4,6,7,10]



[3,1,1,3]



```
vector<int> prevPermOpt1(vector<int>& A) {
    if (is_sorted(A.begin(), A.end())) return A;
    auto i = is_sorted_until(A.rbegin(), A.rend(), greater<>());
    auto j = find_if(A.rbegin(), i, [&](auto e) { return e < *i; });
    iter_swap(i, j);
    return A;
}
```



[thrust::is_sorted](#) [thrust::is_sorted_until](#) [thrust::find_if](#)

1,1,3,3

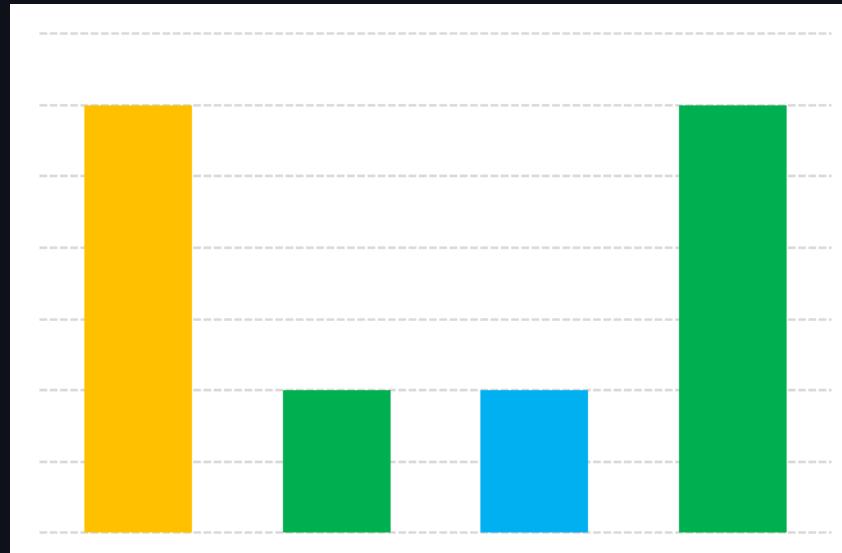
1,3,1,3

1,3,3,1

3,1,1,3

3,1,3,1

3,3,1,1



[3,1,1,3]

1,1,3,3

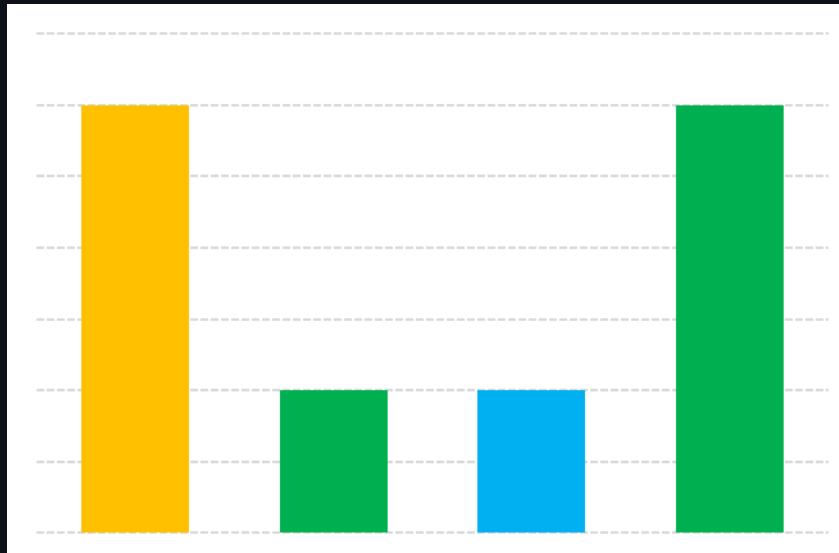
1,3,1,3

1,3,3,1

3,1,1,3

3,1,3,1

3,3,1,1



[3,1,1,3]

1,1,3,3

1,3,1,3

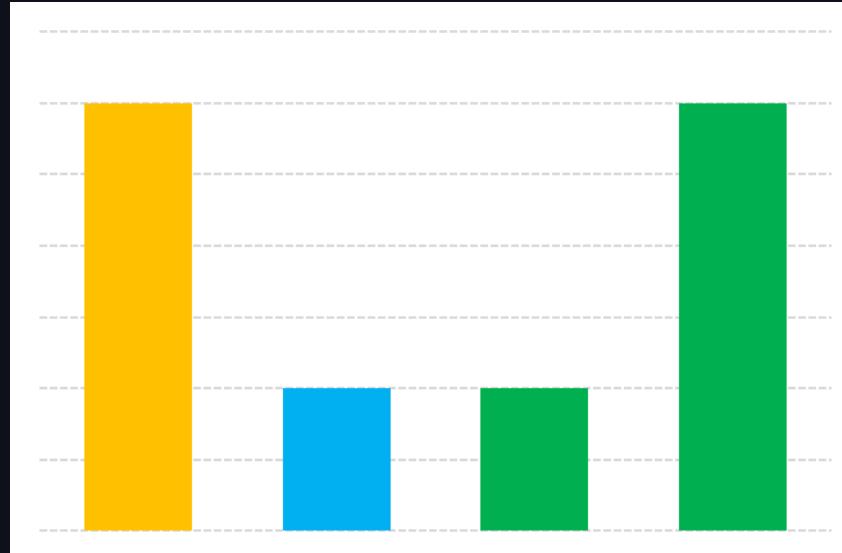
1,3,3,1

3,1,1,3

3,1,3,1

3,3,1,1

1. `is_sort_until` from back -> **i**
2. `find_if < i` from back -> **x**
3. find “range of all values equal to **x**”
4. swap furthest **x** (from back) with **i**



[3,1,1,3]



```
vector<int> prevPermOpt1(vector<int>& A) {
    if (is_sorted(A.begin(), A.end())) return A;
    auto i = is_sorted_until(A.rbegin(), A.rend(), greater<>());
    auto j = find_if(A.rbegin(), i, [&](auto e) { return e < *i; });
    auto p = equal_range(i.base(), A.end(), *j);
    iter_swap(i, p.first);
    return A;
}
```



[thrust::is_sorted](#) [thrust::is_sorted_until](#) [thrust::find_if](#) [thrust::equal_range](#)



```
vector<int> prevPermOpt1(vector<int>& A) {
    auto i = is_sorted_until(A.rbegin(), A.rend(), greater<>());
    if (i != A.rend()) {
        auto j = find_if(A.rbegin(), i, [&](auto e) { return e < *i; });
        auto p = equal_range(i.base(), A.end(), *j);
        iter_swap(i, p.first);
    }
    return A;
}
```



[thrust::is_sorted_until](#) [thrust::find_if](#) [thrust::equal_range](#)

```
// Next, check if the panel has moved to the other side of another panel.  
  
auto p = find_if(begin(expanded_panels_), end(expanded_panels_),  
    [&](const ref_ptr<Panel>& e){ return center_x <= e->cur_panel_center(); });  
  
// Fix this code - panel is the panel found above.  
  
if (panel != fixed_panel) {  
    // If it has, then we reorder the panels.  
    ref_ptr<Panel> ref = expanded_panels_[fixed_index];  
    expanded_panels_.erase(expanded_panels_.begin() + fixed_index);  
    expanded_panels_.insert(expanded_panels_.begin() + i, ref);  
}
```



```
template<typename F, typename T>
F first_less_than(F f, F l, T val) {
    auto it = std::lower_bound(f, l, val);
    return it == f ? l : --it;
}

vector<int> prevPermOpt1(vector<int>& A) {
    auto i = is_sorted_until(A.rbegin(), A.rend(), greater<>());
    if (i != A.rend()) {
        auto j = first_less_than(i.base(), A.end(), *i);
        auto p = equal_range(i.base(), A.end(), *j);
        iter_swap(i, p.first);
    }
    return A;
}
```



[thrust::is_sorted_until](#) [thrust::lower_bound](#) [thrust::equal_range](#)

How many STL algorithms will it take to solve?

1

2

3

4