ALGORITHM INTUITION

Conor Hoekstra

code_report

codereport

2019

“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

cppcon the c++ conference

SCOTT SCHURR

constexpr:
Applications

www.CppCon.org

About Me

- I love C++
- I've been coding in C++ for 5 years*
- I love `auto` (AAA)
- I prefer **east const** (1 const west)
- I prefer "east end functions"

C++ now 2018 MAY 7-11 cppnow.org

Phil Nash

We have always been at war with West Constia

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C++	`auto factorial(int n) -> int`
Rust	`fn factorial(n: i32) -> i32`
Swift	`func factorial(of : Int) -> Int`
Python3	`def factorial(n: int) -> int`
Haskell	`factorial :: (Integral a) => a -> a`
Go	`func factorial(n int) int`
Maths	`f(x) -> y`
Kotlin	`fun factorial(a: Int): Int`

About Me

- I love C++
- I've been coding in C++ for 5 years*
- I love `auto` (AAA)
- I prefer **east const**
- I prefer "east end functions"
- I love (STL) algorithms
- Very interested in programming languages
- I like to compete in competitive programming contests


HackerRank
CODEFORCES
topcoder™
CODECHEF
LeetCode
hackerearth

Let’s go back in time…


Native 2013

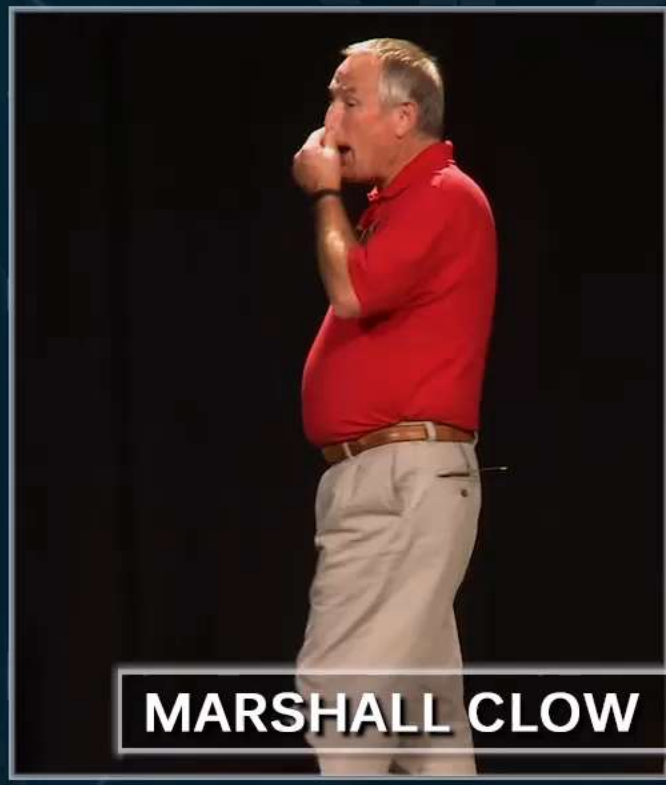
STL Algorithms - How to use them; how to write your own

Marshall Clow
Qualcomm, Inc.

CppCon 2016

mclow@qti.qualcomm.com

@mclow



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

Simplicity is Not Just for Beginners

Idioms, Library Abstractions, Commonality

- These are old friends you can learn to recognize too
- This loop touches every element in the collection; I should use a ranged for instead of a traditional for loop
  - Or something from <algorithm>

We need to know them. All. Well. Very well.

STL algorithms can make code simpler

Sometimes, it can be spectacular.

```
void PanelBar::RepositionExpandedPanels(Panel* fixed_panel) {
  CHECK(fixed_panel);

  // First, find the index of the fixed panel.
  int fixed_index = GetPanelIndex(expanded_panels_, *fixed_panel);
  CHECK_LT(fixed_index, expanded_panels_.size());

  // Next, check if the panel has moved to the other side of another panel.
  const int center_x = fixed_panel->cur_panel_center();
  for (size_t i = 0; i < expanded_panels_.size(); ++i) {
    Panel* panel = expanded_panels_[i].get();
    if (center_x <= panel->cur_panel_center() ||
        i == expanded_panels_.size() - 1) {
      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);
        if (i < expanded_panels_.size()) {
          expanded_panels_.insert(expanded_panels_.begin() + i, ref);
        } else {
          expanded_panels_.push_back(ref);
        }
      }
      break;
    }
  }
```

```
// Next, check if the panel has moved to the left side of another panel.

auto f = begin(expanded_panels_) + fixed_index;

auto p = lower_bound(begin(expanded_panels_), f, center_x,
  [](const ref_ptr<Panel>& e, int x){ return e->cur_panel_center() < x; });

// If it has, then we reorder the panels.
rotate(p, f, f + 1);
```

@JoBoccara

code::dive 2018

@odinthenerd

```
auto result = std::accumulate(
    v.begin(),
    v.end(),
    0,
    better_foo);
```

Auto-Intern GmbH 48

Odin Holmes

What I Wish They Told Me - Part 2 of 2

"… 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."

"… 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

Episode 30

STL implementation

```
template <class I, // I models ForwardIterator
          class T> // T is value_type(I)
I lower_bound(I f, I l, const T& v) {
    while (f != l) {
        auto m = next(f, distance(f, l) / 2);

        if (*m < v) f = next(m);
        else l = m;
    }
    return f;
}
```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SEAN PARENT

Generic Programming

"It's this **phenomenal** piece of work and for me, it was like, **I want to write code like that**."

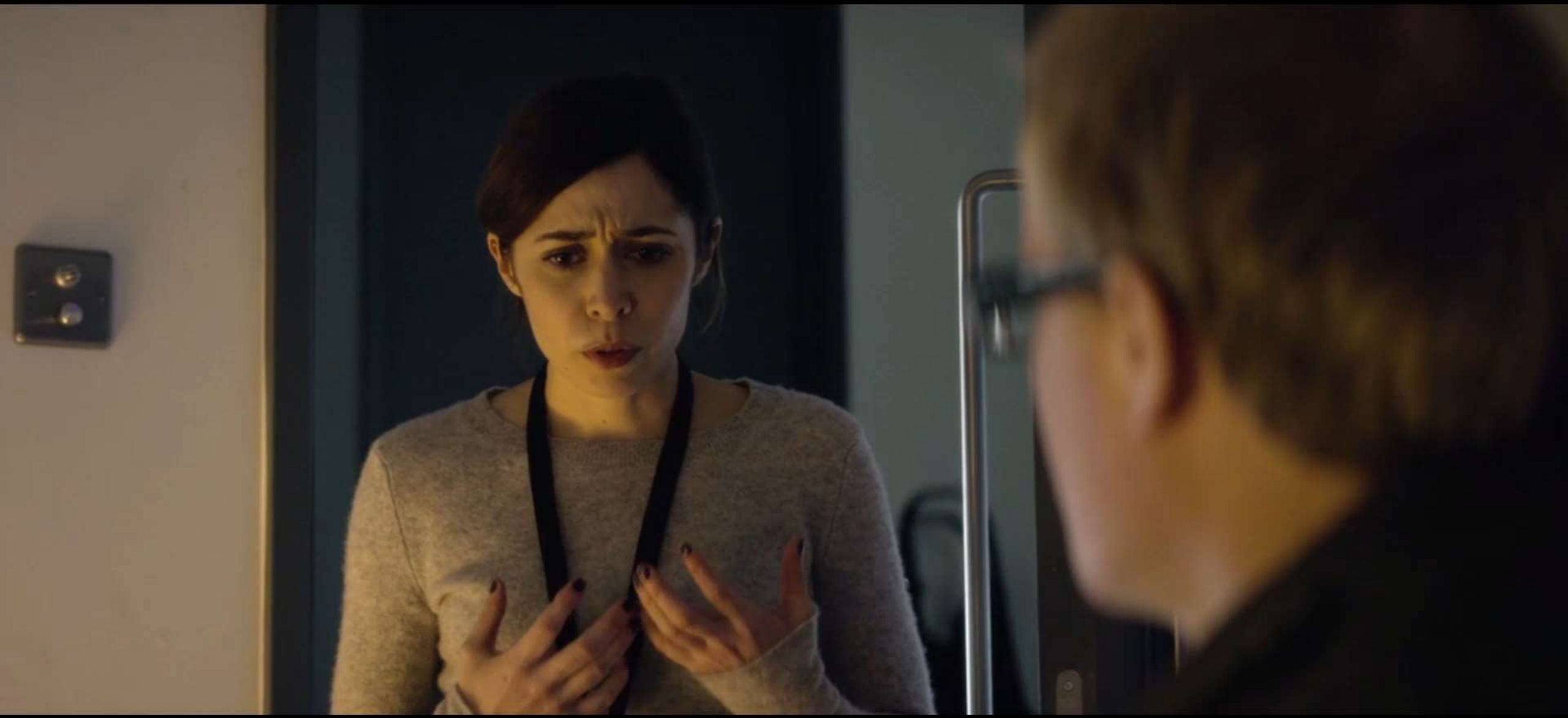
- Sean Parent

Generic Programming, Pacific++ 2018

That is what motivated this talk …

- wanting to develop algorithm intuition
- wanting to write "phenomenal" code
- wanting to write "beautiful code"

NETFLIX



Goal (for you)

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

Interview Warm-up Question

Given an array of integers, find the difference between the minimum and maximum?

Guaranteed to have non-empty list

```cpp
// Solution 1a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto ans = numeric_limits<int>::min();
    for (int i = 0; i < v.size(); ++i) {
        for (int j = 0; j < v.size(); ++j) {
            ans = max(ans, abs(v[i] - v[j]));
        }
    }
    return ans;
}
```

```cpp
// Solution 1b

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto ans = numeric_limits<int>::min();
    for (auto a : v) {
        for (auto b : v) {
            ans = max(ans, abs(a - b));
        }
    }
    return ans;
}
```

```cpp
// Solution 2a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    sort(begin(v), end(v));
    return *--end(v) - *begin(v);
}
```

```cpp
// Solution 2b

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    sort(begin(v), end(v));
    return *rbegin(v) - *begin(v);
}
```

```cpp
// Solution 2c

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    sort(begin(v), end(v));
    return v.back() - v.front();
}
```

```cpp
// Solution 3a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto a = numeric_limits<int>::max();
    auto b = numeric_limits<int>::min();
    for (auto e : v) {
        a = min(a, e);
        b = max(b, e);
    }
    return b - a;
}
```

```cpp
// Solution 3b

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto a = *min_element(begin(v), end(v));
    auto b = *max_element(begin(v), end(v));
    return b - a;
}
```

```cpp
// Solution 3c (C++20 Ranges)

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto a = *min_element(v);
    auto b = *max_element(v);
    return b - a;
}
```

```cpp
// Solution 4a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto p = minmax_element(begin(v), end(v));
    return *p.second - *p.first;
}
```

```cpp
// Solution 4b

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto [a, b] = minmax_element(begin(v), end(v));
    return *b - *a;
}
```

```cpp
// Solution 4c (C++20)

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto [a, b] = minmax_element(v);
    return *b - *a;
}
```

[[Slideware Disclaimer]]

- Should be using std:: namespace
- solve is a terrible function name
- a and b are terrible variable names
- Failing SOLID

[[digression]]

Continuous Learning

Clint Shank

- **Buy low, sell high.** Learning an emerging technology before it becomes popular can be just as hard as finding an undervalued stock, but the payoff can be just as rewarding. Learning Java when it first came out may have been risky, but it paid off handsomely for the early adopters who are now at the top of that field.
- **Review and rebalance.** This is a very dynamic industry. That hot technology you started investigating last month might be stone cold

- **Learn at least one new language every year.** Different languages solve the same problems in different ways. By learning several different approaches, you can help broaden your thinking and avoid getting stuck in a rut. Additionally, learning many languages is far

Goals

Now that you have some guidelines on what and when to add to your knowledge portfolio, what's the best way to go about acquiring intellectual capital with which to fund your portfolio? Here are a few suggestions.

- **Learn at least one new language every year.** Different languages solve the same problems in different ways. By learning several different approaches, you can help broaden your thinking and avoid getting stuck in a rut. Additionally, learning many languages is far easier now, thanks to the wealth of freely available software on the Internet (see page 267).
- **Read a technical book each quarter.** Bookstores are full of technical books on interesting topics related to your current project. Once you're in the habit, read a book a month. After you've mastered the technologies you're currently using, branch out and study some that *don't* relate to your project.
- **Read nontechnical books, too.** It is important to remember that computers are used by *people*—people whose needs you are trying to satisfy. Don't forget the human side of the equation.

https://launchschool.com/blog/mutating-and-non-mutating-methods


```
1  >> s = '   hey   '
2  => "   hey   "
7  >> s.strip!
8  => "hey"
```

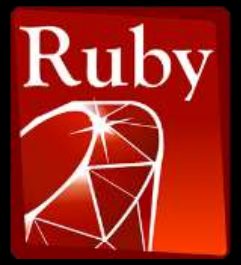
```cpp
// Solution 4a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto p = minmax_element(begin(v), end(v));
    return *p.second - *p.first;
}
```

Many, but not all, methods that mutate their receiver use `!` as the last character of their name. However, this is not guaranteed to be the case. For instance, `String#concat` is a mutating method, but it does not include a `!`.

[[digression²]]

What does “!” mean?



Mutating method

Macro
(lisp style, not C style)

Template type

Strictness

[[end digression^2]]

```cpp
// Solution 4a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto p = minmax_element(begin(v), end(v));
    return *p.second - *p.first;
}
```

```cpp
// Solution 4a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto p = minmax_element(cbegin(v), cend(v));
    return *p.second - *p.first;
}
```

```cpp
// Solution 4a

auto solve() -> int {
    vector v = { 2, 1, 3, 5, 4 };
    auto p = minmax_element(cbegin(v), cend(v));
    return *p.second - *p.first;
}
```

[[end digression]]

```python
def solve() -> int:
    l = [ 2, 1, 3, 5, 4 ]
    return max(l) - min(l)
```


```java
public static int solve() {
    List<Integer> l = Arrays.asList( 2, 1, 5, 3, 4 );
    int a = Collections.min(l);
    int b = Collections.max(l);
    return b - a;
}
```

```haskell
solve :: [Int] -> Int
solve xs = maximum xs - minimum xs
```

105 Algorithms?

We need to know them. All. Well. Very well.

STL algorithms can make code simpler

Sometimes, it can be spectacular.

```
void PanelBar::RepositionExpandedPanels(Panel* fixed_panel) {
  CHECK(fixed_panel);

  // First, find the index of the fixed panel.
  int fixed_index = GetPanelIndex(expanded_panels_, *fixed_panel);
  CHECK_LT(fixed_index, expanded_panels_.size());

  // Next, check if the panel has moved to the other side of another panel.
  const int center_x = fixed_panel->cur_panel_center();
  for (size_t i = 0; i < expanded_panels_.size(); ++i) {
    Panel* panel = expanded_panels_[i].get();
    if (center_x <= panel->cur_panel_center() ||
        i == expanded_panels_.size() - 1) {
      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);
        if (i < expanded_panels_.size()) {
          expanded_panels_.insert(expanded_panels_.begin() + i, ref);
        } else {
          expanded_panels_.push_back(ref);
        }
      }
      break;
    }
  }
```

```
// Next, check if the panel has moved to the left side of another panel.

auto f = begin(expanded_panels_) + fixed_index;

auto p = lower_bound(begin(expanded_panels_), f, center_x,
  [](const ref_ptr<Panel>& e, int x){ return e->cur_panel_center() < x; });

// If it has, then we reorder the panels.
rotate(p, f, f + 1);
```

@JoBoccara

Hi, I'm Jonathan Boccara!

@JoBoccara

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105 STL Algorithms in Less Than an Hour

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71 Algorithms
+ 32 Runes
103 Algorithms
Secret Runes
stable_*
*_copy
*_n
*_if
is_*_until
is_*
Province of Value Queries
Province of Property Queries
Province of 2-Ranges Properties
Glorious County of Algos on Sets
Peninsula of ...w Memory
Territory of Movers
Island of Structure Changers
Land of Value Modifiers
The World of C++ STL Algorithms


71 Algorithms
+ 32 Runes
---
103 Algorithms
105 Algorithms?
What are the missing 2?
Secret Runes
stable_*
*_copy
*_n
*_if
is_*_until
is_*
clamp
destroy_at
find_if_not
iter_swap
max
min
minmax
swap
The World of C++ STL Algorithms

Conor Hoekstra
@code_report

@JoBoccara What are the two missing algorithms that get us to 105? clamp? destroy_at? find_if_not? iter_swap? max? min?

Jonathan Boccara @JoBoccara · May 5

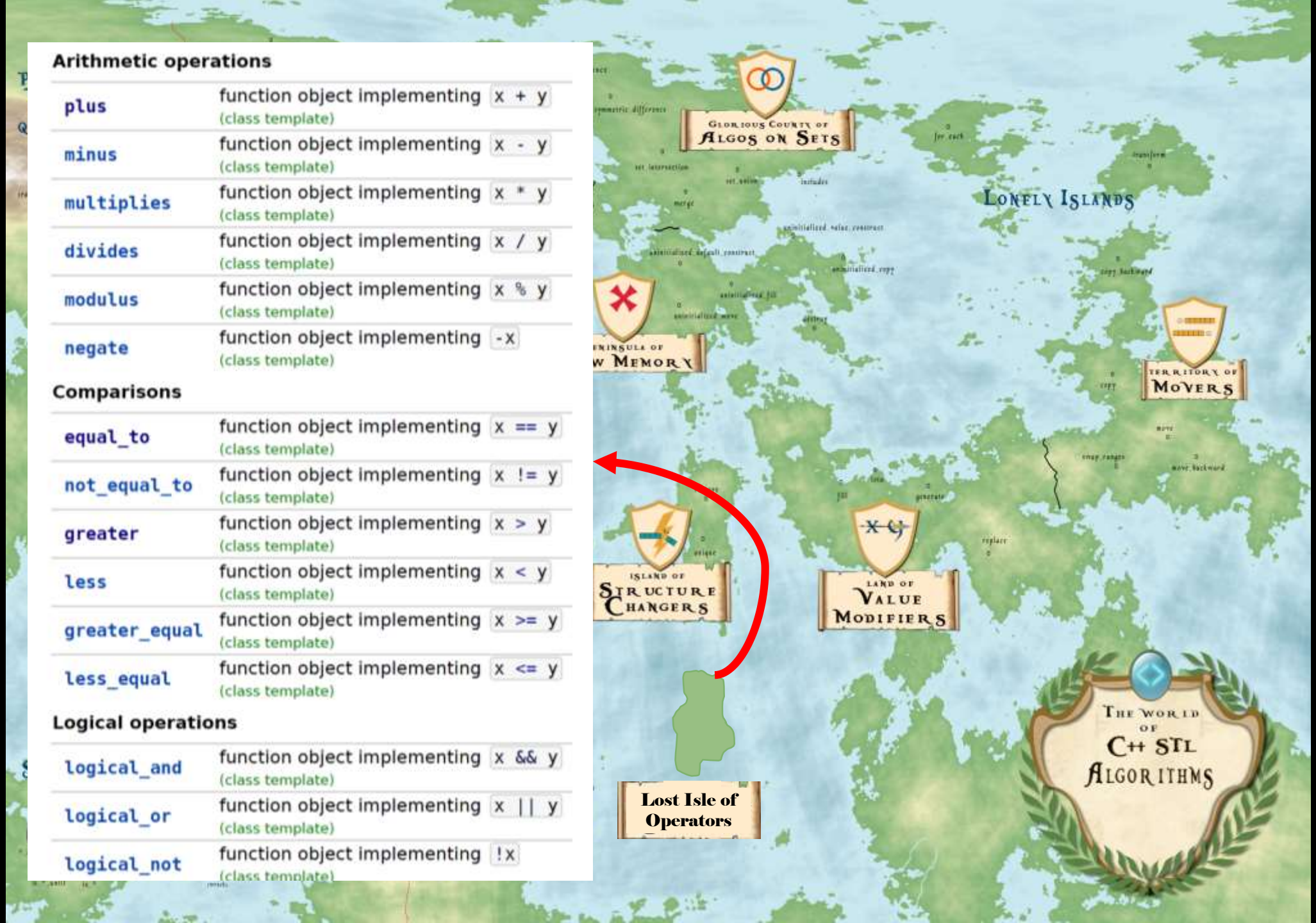
Replying to @code_report @cppnow

Hi, find_if_not is indeed counted as it's in the slides. Not the others you're mentioning as as they doesn't take a begin and end. I've looked up your talk's abstract at C++Now. Would love to watch it when it's online (I won't be there this year)

1:30 AM - 1 May 2019


clamp
destroy_at
find_if_not
iter_swap
max
min
minmax
swap


clamp
destroy_at
find_if_not
iter_swap
max
min
minmax
swap



Arithmetic operations

`plus`	function object implementing `x + y` (class template)
`minus`	function object implementing `x - y` (class template)
`multiplies`	function object implementing `x * y` (class template)
`divides`	function object implementing `x / y` (class template)
`modulus`	function object implementing `x % y` (class template)
`negate`	function object implementing `-x` (class template)

Comparisons

`equal_to`	function object implementing `x == y` (class template)
`not_equal_to`	function object implementing `x != y` (class template)
`greater`	function object implementing `x > y` (class template)
`less`	function object implementing `x < y` (class template)
`greater_equal`	function object implementing `x >= y` (class template)
`less_equal`	function object implementing `x <= y` (class template)

Logical operations

`logical_and`	function object implementing `x && y` (class template)
`logical_or`	function object implementing `x || y` (class template)
`logical_not`	function object implementing `!x` (class template)

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

Can anyone name one of the **four original numeric** algorithms?
Can anyone name the **one C++11 numeric** algorithms?

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

accumulate	partial_sum
adjacent_difference	reduce
exclusive_scan	transform_exclusive_scan
inclusive_scan	transform_inclusive_scan
inner_product	transform_reduce
iota	

Pre-C++11	C++11	C++17

```cpp
vector<int> v(10);
iota(begin(v), end(v), 1);

// 1 2 3 4 5 6 7 8 9 10
```

```cpp
vector<int> v(10);
iota(rbegin(v), rend(v), 1);

// 10 9 8 7 6 5 4 3 2 1
```

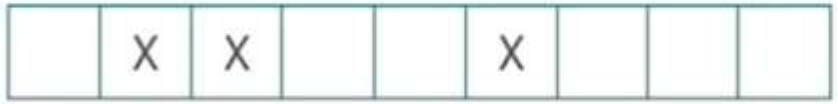
#iotashaming

accumulate	partial_sum
adjacent_difference	reduce
exclusive_scan	transform_exclusive_scan
inclusive_scan	transform_inclusive_scan
inner_product	transform_reduce
iota 	

Pre-C++11	C++11	C++17

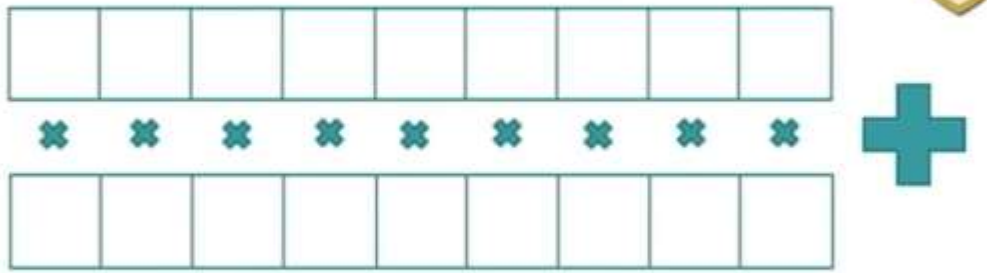
NUMERIC ALGORITHMS

count



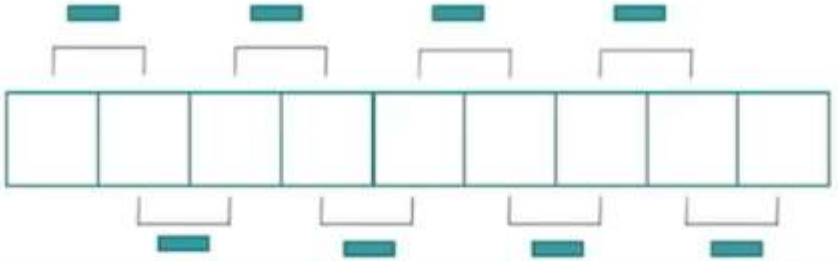
3

inner_product

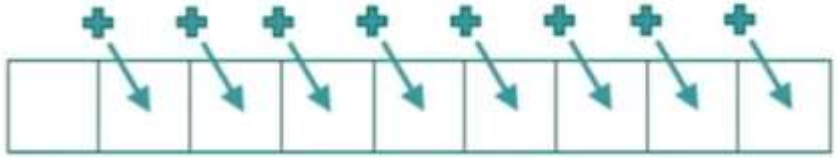


accumulate/(transform_)reduce

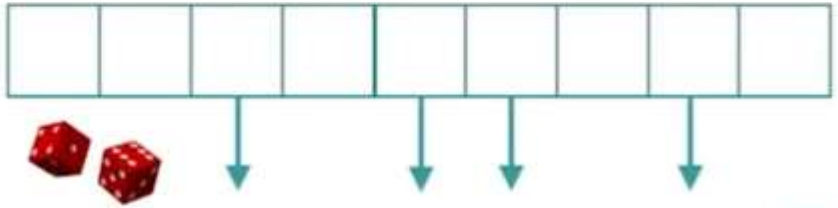
adjacent_difference



partial_sum
(transform_)inclusive_scan
(transform_)exclusive_scan



sample



@JoBoccara

```
vector v = { 1, 2, 3 };

auto x = accumulate(cbegin(v), cend(v), 0);
```

```
vector v = { 1, 2, 3 };

auto x = accumulate(cbegin(v), cend(v), 0);
auto y = accumulate(cbegin(v), cend(v), 0, plus{});
```

Not the best name …

```
vector v = { 1, 2, 3 };

auto x = accumulate(cbegin(v), cend(v), 0);
auto y = accumulate(cbegin(v), cend(v), 1, multiplies{});
```

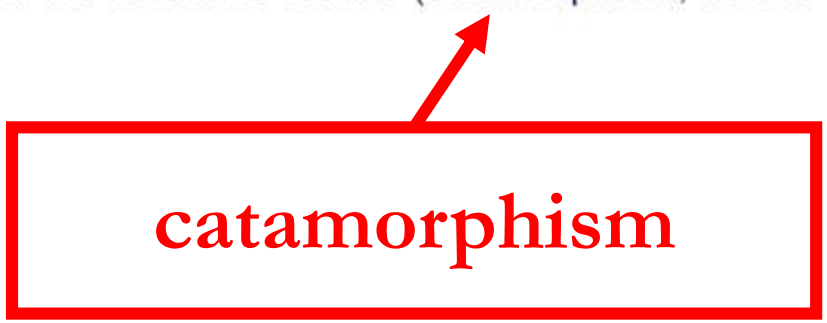
```
vector v = { 1, 2, 3 };

auto x = reduce(cbegin(v), cend(v));
auto y = reduce(cbegin(v), cend(v), 0, plus{});
auto z = reduce(cbegin(v), cend(v), 1, multiplies{});
```

Fold (higher-order function)

From Wikipedia, the free encyclopedia

In functional programming, **fold** (also termed **reduce**, **accumulate**, **aggregate**, **compress**, or **inject**) refers to a family of higher-order functions that analyze a recursive data structure and through use of a given combining operation, recombine the results of recursively processing its constituent parts, building up a return value. Typically, a fold is presented with a combining function, a top node of a data structure, and possibly some default values to be used under certain conditions. The fold then proceeds to combine elements of the data structure's hierarchy, using the function in a systematic way.

Folds are in a sense dual to unfolds, which take a *seed* value and apply a function corecursively to decide how to progressively construct a corecursive data structure, whereas a fold recursively breaks that structure down, replacing it with the results of applying a combining function at each node on its terminal values and the recursive results (catamorphism, versus anamorphism of unfolds).



```rust
fn fold<B, F>(self, init: B, f: F) -> B
where
    F: FnMut(B, Self::Item) -> B,
```

An iterator method that applies a function, producing a single, final value.

`fold()` takes two arguments: an initial value, and a closure with two arguments: an 'accumulator', and an element. The closure returns the value that the accumulator should have for the next iteration.

The initial value is the value the accumulator will have on the first call.

After applying this closure to every element of the iterator, `fold()` returns the accumulator.

This operation is sometimes called 'reduce' or 'inject'.

Folding is useful whenever you have a collection of something, and want to produce a single value from it.

Note: `fold()`, and similar methods that traverse the entire iterator, may not terminate for infinite iterators, even on traits for which a result is determinable in finite time.

Template `std.algorithm.iteration.fold`

Implements the homonym function (also known as `accumulate`, `compress`, `inject`, or `foldl`) present in various programming languages of functional flavor. The call `fold!(fun)(range, seed)` first assigns `seed` to an internal variable `result`, also called the accumulator. Then, for each element `x` in `range`, `result = fun(result, x)` gets evaluated. Finally, `result` is returned. The one-argument version `fold!(fun)(range)` works similarly, but it uses the first element of the range as the seed (the range must be non-empty).

Template `std.algorithm.iteration.reduce`

Implements the homonym function (also known as `accumulate`, `compress`, `inject`, or `foldl`) present in various programming languages of functional flavor. There is also `fold` which does the same thing but with the opposite parameter order. The call `reduce!(fun)(seed, range)` first assigns `seed` to an internal variable `result`, also called the accumulator. Then, for each element `x` in `range`, `result = fun(result, x)` gets evaluated. Finally, `result` is returned. The one-argument version `reduce!(fun)(range)` works similarly, but it uses the first element of the range as the seed (the range must be non-empty).

We can use reduce to implement other algorithms…

```
vector v = { 1, 2, 3, 1, 2 };

auto x =  my::count(cbegin(v), cend(v), 1);
auto y = std::count(cbegin(v), cend(v), 1);
```

```cpp
namespace my {
    template<class I, class T>
    auto count(I f, I l, T const& val) -> int {
        return std::reduce(f, l, 0,
            [val](auto a, auto b) { return a + (b == val); });
    }
}
```

```cpp
vector v = { 1, 2, 3 };

auto x =  my::any_of(cbegin(v), cend(v), [](auto e) { return e == 3; });
auto y = std::any_of(cbegin(v), cend(v), [](auto e) { return e == 3; });
```

```cpp
namespace my {
    template<class I, class P>
    auto any_of(I f, I l, P p) -> bool {
        return std::reduce(f, l, false,
            [p](auto a, auto b) { return a || p(b); });
    }
}
```

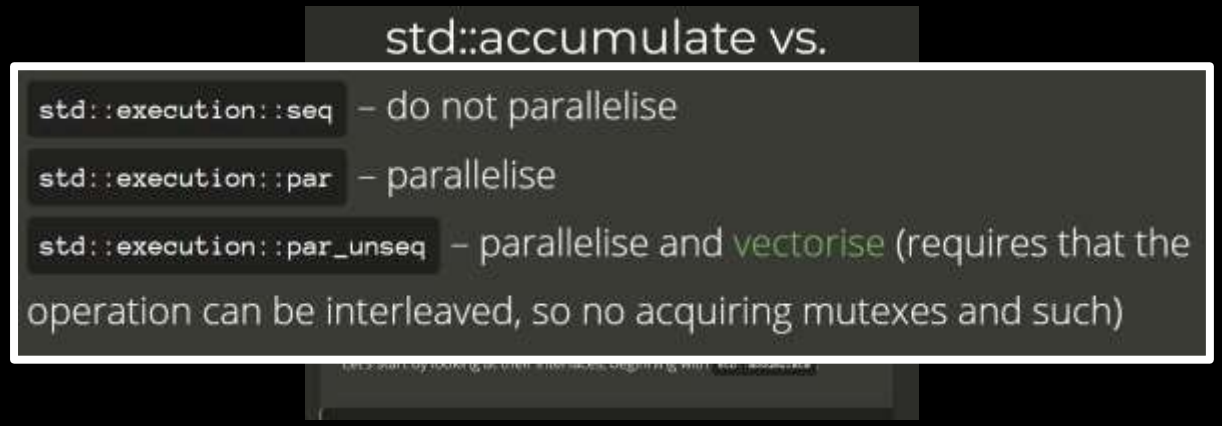

count
any_of
all_of
none_of
Province of Value Queries
Province of Property Queries
Province of Ranges Properties
Glorious County of Algos on Sets
is_permutation
Lonely Islands
find
transform_reduce
adjacent_find
inner_product
reduce
accumulate
Peninsula of Raw Memory
Territory of Movers
Province of Research
min_element
max_element
minmax_element
Island of Structure Changers
Land of Value Modifiers
partition_point
Secret Runes
Lands of Permutations
The World of C++ STL Algorithms

```
vector v = { 1, 2, 3 };

auto x = reduce(cbegin(v), cend(v));
auto y = reduce(cbegin(v), cend(v), 0, plus<>());
auto z = reduce(cbegin(v), cend(v), 1, multiplies<>());
```

std::execution::sequenced_policy, std::execution::parallel_policy, std::execution::parallel_unsequenced_policy

Defined in header <execution>

`class sequenced_policy { /* unspecified */ };`	(1)	(since C++17)
`class parallel_policy { /* unspecified */ };`	(2)	(since C++17)
`class parallel_unsequenced_policy { /* unspecified */ };`	(3)	(since C++17)



https://blog.tartanllama.xyz/accumulate-vs-reduce/

https://www.youtube.com/watch?v=FJIn1YhPJJc

accumulate	partial_sum
adjacent_difference	reduce
exclusive_scan	transform_exclusive_scan
inclusive_scan	transform_inclusive_scan
inner_product	transform_reduce
iota	

https://cdn-images-1.medium.com/max/1200/0*eRRsfXUmbpH2Oq_N.jpg
Baby image credit

Jon Kalb is going to give Michael a
with different values. Jon wants the
of the coins to be minimized so Mi
other. Given an array of coin value

1 4 2

1 3 3

https://www.codechef.com/problems/EID

```cpp
auto min_value(vector<int>& coins) -> int {
    sort(begin(coins), end(coins));
    vector<int> diff(v.size ());
    adjacent_difference(cbegin(coins), cend(coins), begin (diff));
    return *min_element(cbegin(diff) + 1, cend(diff));
}
```

https://www.codechef.com/problems/EID

What's wrong with 2nd line? Do we O(n) space? Think catamorphism

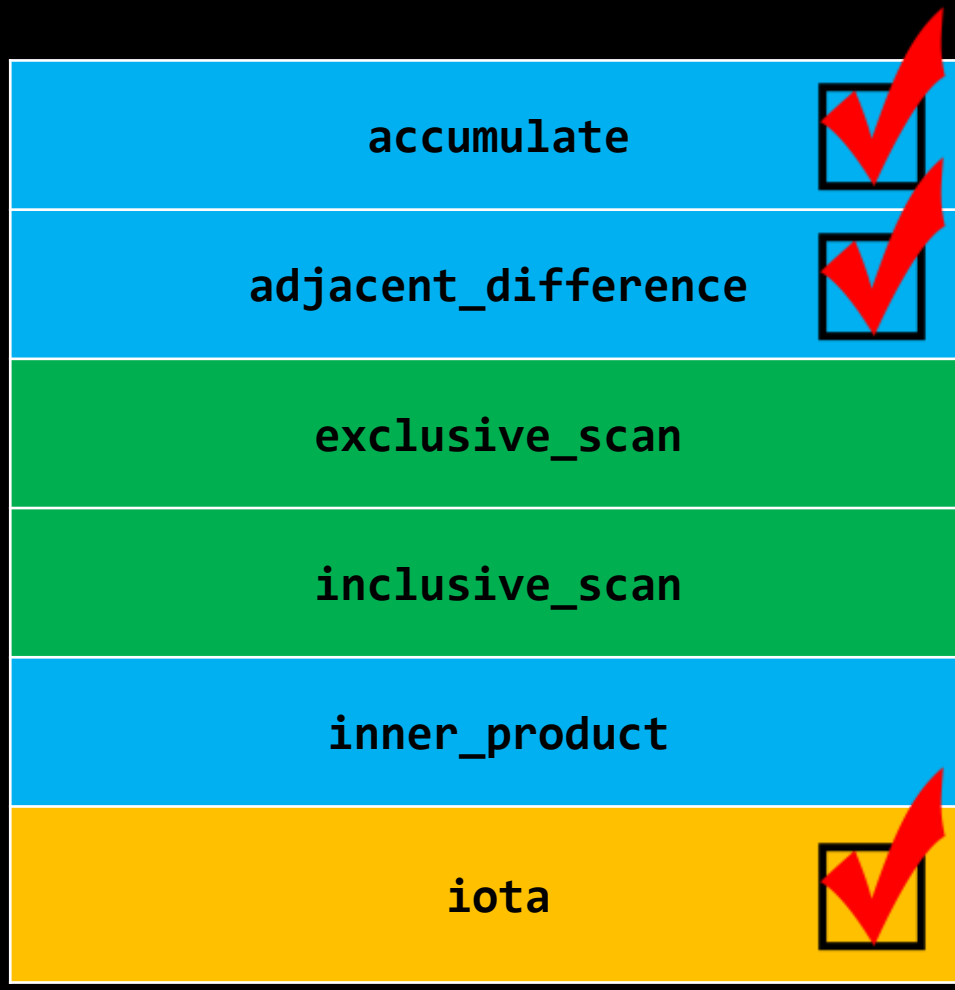
```
auto min_value(vector<int>& c) -> int {
    sort(begin(c), end(c));
    vector<int> d(v.size ());
    adjacent_difference(cbegin(c), cend(c), begin(d));
    return *min_element(cbegin(d) + 1, cend(d));
}
```

https://www.codechef.com/problems/EID

```cpp
auto min_value(vector<int>& c) -> int {
    sort(begin(c), end(c));
    return reduce(cbegin(c) + 1, cend(c), numeric_limits<int>::max(),
        [prev = c.front()](auto a, auto b) mutable {
            auto d = b - prev;
            prev = b;
            return min(a, d);
        });
}
```

https://www.codechef.com/problems/EID

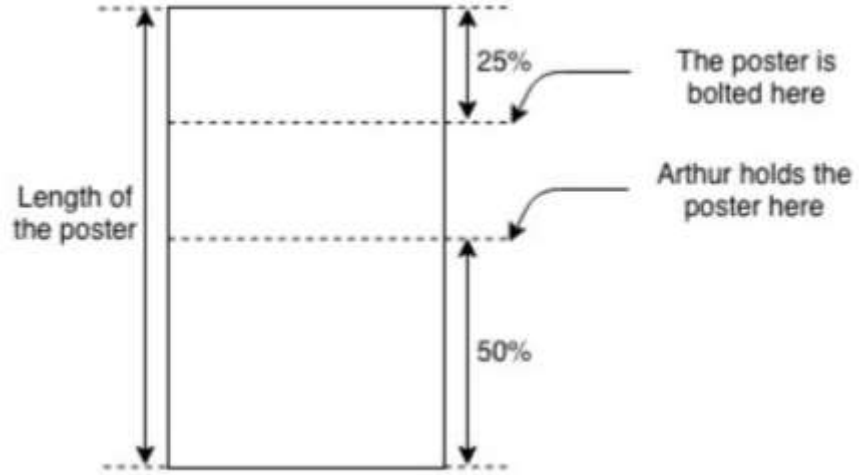
accumulate	partial_sum
adjacent_difference	reduce
exclusive_scan	transform_exclusive_scan
inclusive_scan	transform_inclusive_scan
inner_product	transform_reduce
iota	



Pre-C++11	C++11	C++17

HackerRank

You are given the length (l) of N posters, and the wall heights (w) at which they will be hung. They are hung at they 75% mark of the poster. Given Chandler has height h, how tall a ladder does he need?

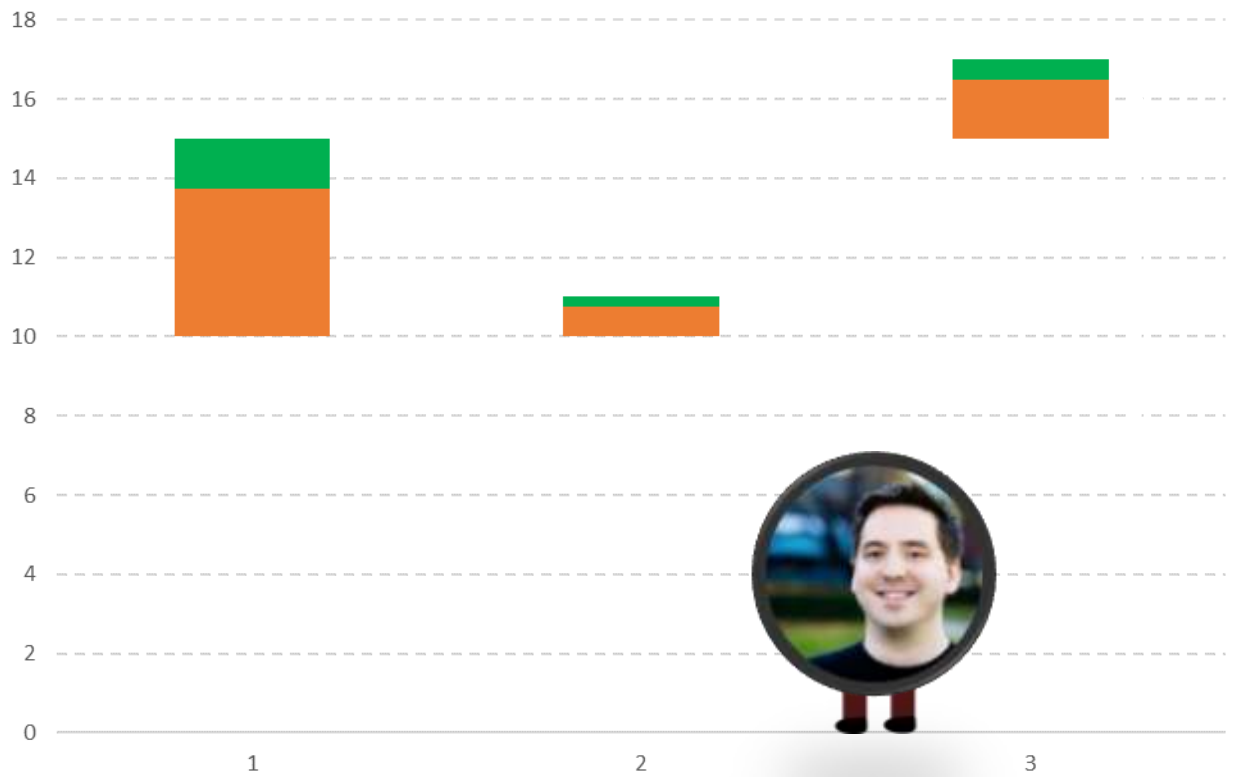


https://www.hackerrank.com/contests/hourrank-31/challenges/hanging-posters/problem

HourRank 31: Problem 1 – Hanging Posters

```
3  5
15  11  17
5  1  2
```

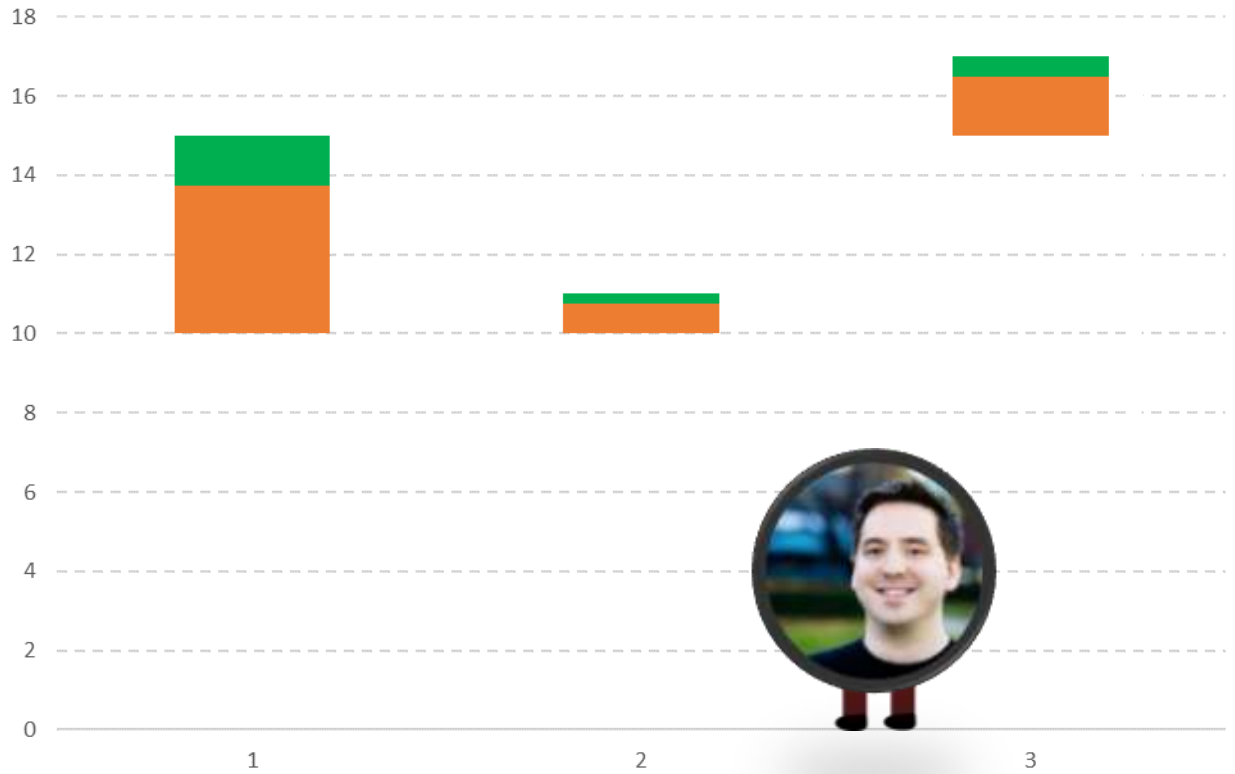
$$ceil\left(w - \frac{l}{4}\right) - h = 12$$



HourRank 31: Problem 1 – Hanging Posters

```
3  5
15  11  17
5  1  2
```

$$ceil\left(w - \frac{l}{4}\right) - h = 12$$



```cpp
int solve(int h, vector<int> w, vector<int> l) {
    int p = 0;
    for (int i = 0; i < w.size(); ++i)
        p = max(p, w[i] - l[i] / 4);
    return max(0, p - h);
}
```

```java
public static int solve(int h, List<Integer> w, List<Integer> l) {
    int p = 0;
    for (int i = 0; i < w.size(); ++i)
        p = Math.max(p, w.get(i) - l.get(i)/4);
    return Math.max(0, p - h);
}
```

Then Simon Brand tweeted…

```
def solve(h, w, l):
    p = max(a - b//4 for a, b in zip(w, l))
    return max(0, p - h)
```

```
int main() {
    auto hamming_distance = [](auto&& r1, auto&& r2) {
        return accumulate(view::zip(r1, r2), 0, ranges::plus{},
            [](auto&& x) { return x.first != x.second; });
    };

    auto ns = ranges::istream_range<std::string>(std::cin) | to_vector;
    auto found = view::cartesian_product(ns, ns)
                 | view::filter([&](auto&& p) {
                     return hamming_distance(get<0>(p), get<1>(p)) == 1;
                   });
    for (auto [s1,s2] : found | view::take(1)) {
        for (auto[c1, c2] : view::zip(s1, s2)) {
            if (c1 == c2) std::cout << c1;
        }
    }
}
```

Conor Hoekstra @code_report · 3 Dec 2018

Replying to @TartanLlama

Omgoodness! Ranges comes with zip??? Please tell me this is coming with C++20.

1 1

Simon Brand @TartanLlama · 3 Dec 2018

Parts of range-v3 are coming in 20, I don't believe zip is though. @cjdb_ns ?

1

Conor Hoekstra @code_report · 3 Dec 2018

This makes me so incredibly happy! I literally just yesterday googled, C++17 / C++20 zip to see if they had anything, because I wrote some code in both C++ and #Python and Python was so much more beautiful.

```cpp
int solve(int h, vector<int> w, vector<int> l) {
    int p = 0;
    for (int i = 0; i < w.size(); ++i)
        p = max(p, w[i] - l[i] / 4);
    return max(0, p - h);
}
```

```python
def solve(h, w, l):
    p = max(a - b//4 for a, b in zip(w, l))
    return max(0, p - h)
```

2 1 2

Conor Hoekstra @code_report · 16 Dec 2018

Also, I just discovered std::inner_product - a beautiful temporary solution to a lack of zip. #cpp #inner_product

```
int solve(int h, vector<int> w, vector<int> l) {
    return max(0, inner_product(begin(w), end(w), begin(l), 0,
        [](auto a, auto b) { return max(a, b); },
        [](auto a, auto b) { return a - b / 4; }) - h);
}
```

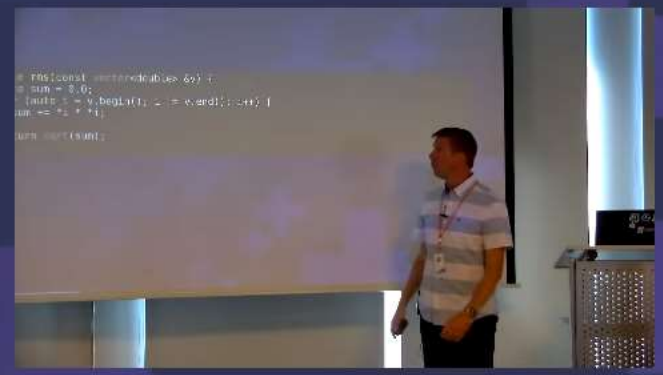


2


avast
WHY C++ ISN'T DEAD
MATT GODBOLT
@MATTGODBOLT
AVAST, JUNE 2018
C++ meetup
PRAGUE
Avast Events System
231 subscribers

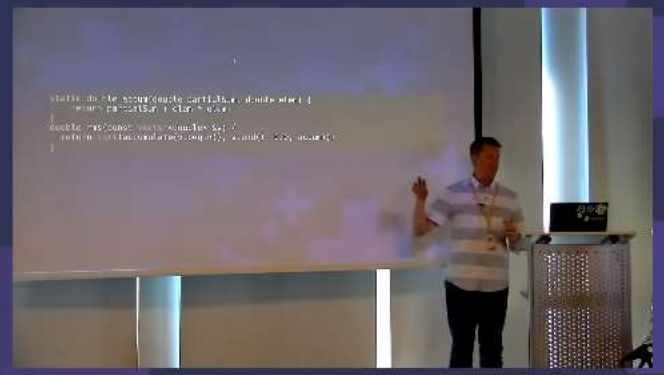
```
double rms(const vector<double> &v) {
  double sum = 0.0;
  for (vector<double>::const_iterator i = v.begin();
       i != v.end();
       i++) {
    sum += *i * *i;
  }
  return sqrt(sum);
}
```

```
double rms(const vector<double> &v) {
  auto sum = 0.0;
  for (auto i = v.begin(); i != v.end(); i++) {
    sum += *i * *i;
  }
  return sqrt(sum);
}
```



```
double rms(const vector<double> &v) {
  auto sum = 0.0;
  for (auto i : v)
    sum += i * i;
  return sqrt(sum);
}
```

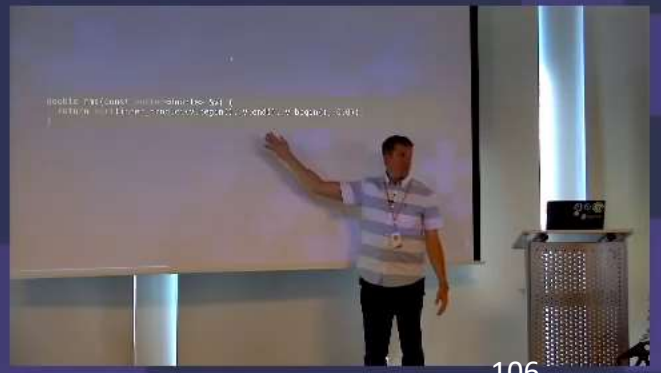
```
static double accum(double partialSum, double elem) {
    return partialSum + elem * elem;
}
double rms(const vector<double> &v) {
  return sqrt(accumulate(v.begin(), v.end(), 0.0, accum));
}
```



```
double rms(const vector<double> &v) {
  return sqrt(accumulate(
      v.begin(), v.end(), 0.0,
      [](double partialSum, double elem) {
          return partialSum + elem * elem;
      }
  ));
}
```

```
double rms(const vector<double> &v) {
  return sqrt(inner_product(v.begin(), v.end(), v.begin(), 0.0));
}
```

```
double rms(const vector<double> &v) {
  return sqrt(inner_product(v.begin(), v.end(), v.begin(), 0.0));
}
```



Not the best name …

Conor Hoekstra @code_report · 16 Dec 2018

Also, I just discovered std::inner_product - a beautiful temporary solution to a lack of zip. #cpp #inner_product

```
int solve(int h, vector<int> w, vector<int> l) {
    return max(0, inner_product(begin(w), end(w), begin(l), 0,
        [](auto a, auto b) { return max(a, b); },
        [](auto a, auto b) { return a - b / 4; }) - h);
}
```

2

And then …



transform_reduce



```
vector v = { 1, 2, 3 };
vector u = { 2, 3, 4 };

auto x = transform_reduce(cbegin(v), cend(v), cbegin(u), 0);
```

```
vector v = { 1, 2, 3 };
vector u = { 2, 3, 4 };

auto x = transform_reduce(cbegin(v), cend(v), cbegin(u), 0);
auto y = transform_reduce(cbegin(v), cend(v), cbegin(u), 0, plus{}, multiplies{});
```

```
vector v = { 1, 2, 3 };
vector u = { 2, 3, 4 };

auto x = transform_reduce(cbegin(v), cend(v), cbegin(u), 0);
auto y = transform_reduce(cbegin(v), cend(v), cbegin(u), 0, plus{}, multiplies{});
auto z = transform_reduce(cbegin(v), cend(v), cbegin(u), 0,
   plus{},
   multiplies{});
```

```
vector v = { 1, 2, 3 };
vector u = { 2, 3, 4 };

auto x = transform_reduce(cbegin(v), cend(v), cbegin(u), 0);
auto y = transform_reduce(cbegin(v), cend(v), cbegin(u), 0, plus{}, multiplies{});
auto z = transform_reduce(cbegin(v), cend(v), cbegin(u), 0,
   [](auto a, auto b) { return max(a, b); },
   multiplies{});
```

Why not call it zip_reduce? Doesn't need to zip!!

```
vector v = { 1, 2, 3 };
vector u = { 2, 3, 4 };

auto x = transform_reduce(cbegin(v), cend(v), cbegin(u), 0);
auto y = transform_reduce(cbegin(v), cend(v), cbegin(u), 0, plus{}, multiplies{});
auto z = transform_reduce(cbegin(v), cend(v), cbegin(u), 0,
   [](auto a, auto b) { return max(a, b); },
   [](auto a, auto b) { return a + b * b; });
```

std::transform_reduce

Defined in header <numeric>

```
template<class InputIt1, class InputIt2, class T>
T transform_reduce(InputIt1 first1, InputIt1 last1, InputIt2 first2, T init);
```
(1) (since C++17)

```
template <class InputIt1, class InputIt2, class T, class BinaryOp1, class BinaryOp2>
T transform_reduce(InputIt1 first1, InputIt1 last1, InputIt2 first2,
                   T init, BinaryOp1 binary_op1, BinaryOp2 binary_op2);
```
(2) (since C++17)

```
template<class InputIt, class T, class BinaryOp, class UnaryOp>
T transform_reduce(InputIt first, InputIt last,
                   T init, BinaryOp binop, UnaryOp unary_op);
```
(3) (since C++17)

```
template<class ExecutionPolicy,
         class ForwardIt1, class ForwardIt2, class T>
T transform_reduce(ExecutionPolicy&& policy,
                   ForwardIt1 first1, ForwardIt1 last1, ForwardIt2 first2, T init);
```
(4) (since C++17)

```
template<class ExecutionPolicy,
         class ForwardIt1, class ForwardIt2, class T, class BinaryOp1, class BinaryOp2>
T transform_reduce(ExecutionPolicy&& policy,
                   ForwardIt1 first1, ForwardIt1 last1, ForwardIt2 first2,
                   T init, BinaryOp1 binary_op1, BinaryOp2 binary_op2);
```
(5) (since C++17)

```
template<class ExecutionPolicy,
         class ForwardIt, class T, class BinaryOp, class UnaryOp>
T transform_reduce(ExecutionPolicy&& policy,
                   ForwardIt first, ForwardIt last,
                   T init, BinaryOp binary_op, UnaryOp unary_op);
```
(6) (since C++17)

```
vector v = { 1, 2, 3 };

auto x = reduce(cbegin(v), cend(v), 0,
    [](auto a, auto b) { return a + b * b; });

auto y = transform_reduce(cbegin(v), cend(v), 0,
    std::plus{},
    [](auto e) { return e * e; });
```

Let's revisit our adjacent_difference / reduce question

```cpp
auto min_value(vector<int>& c) {
    sort(begin(c), end(c));
    return reduce(cbegin(c) + 1, cend(c), numeric_limits<int>::max(),
        [prev = c.front()](auto a, auto b) mutable {
        auto d = abs(b - prev);
        prev = b;
        return min(a, d);
    });
}
```

https://www.codechef.com/problems/EID

Can anyone see how to improve this?
Hint: make use of a std:: function object

```
auto min_value(vector<int>& c) {
   sort(begin(c), end(c));
   return transform_reduce(cbegin(c), --cend(c), ++cbegin(c),
      numeric_limits<int>::max(),
      [](auto a, auto b) { return min(a, b); },
      [](auto a, auto b) { return abs(a - b); });
}
```

https://www.codechef.com/problems/EID

```cpp
auto min_value(vector<int>& c) {
    sort(begin(c), end(c));
    return transform_reduce(++cbegin(c), cend(c), cbegin(c),
        numeric_limits<int>::max(),
        [](auto a, auto b) { return min(a, b); },
        std::minus{});
}
```

https://www.codechef.com/problems/EID

```haskell
min_value :: [Int] -> Int
min_value = minimum . mapAdjacent (flip (-)) . sort
```

https://www.codechef.com/problems/EID

```
[1,4,2]
[1,2,4]
[1,2]
1
```

```haskell
min_value :: [Int] -> Int
min_value = minimum
          . mapAdjacent (flip (-))
          . sort
```

https://www.codechef.com/problems/EID

[[digression]]

Composition

Task: Count repeated values

- I couldn't believe it when I saw this
- Ivan says three really important things:
  - "**inner_product** is a really cool example that **you should never use**"
  - "**transform_reduce sounds much nicer** … but the problem is a little bit bigger than just the name"
  - "we have three different operations [zip, transform, reduce] but since we have the iterators and **iterators are not easily composable** this could not have just been three different algorithms – this needs to be a single algorithm that is a composition of all the previous three"

```cpp
auto count_adj_equals(vector<int> const& v) -> int {
    vector d(v.size(), 0);
    adjacent_difference(cbegin(v), cend(v), begin(d));
    return count_if(cbegin(d) + 1, cend(d),
            [](auto e) { return e == 0; });
}
```

https://www.codechef.com/problems/EID

```
[1,1,0,0,2,2,3]
[0,1,0,-2,0,-1]
3
```

```haskell
count_if f = length . filter f
adj_diff   = mapAdjacent (-)

count_adj_equals :: [Int] -> Int
count_adj_equals = count_if (==0) . adj_diff
```

https://www.codechef.com/problems/EID

[[end digression]]

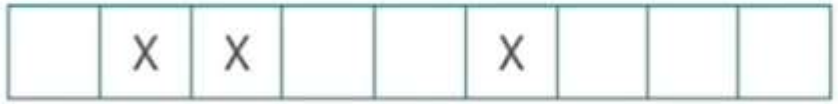


transform_reduce

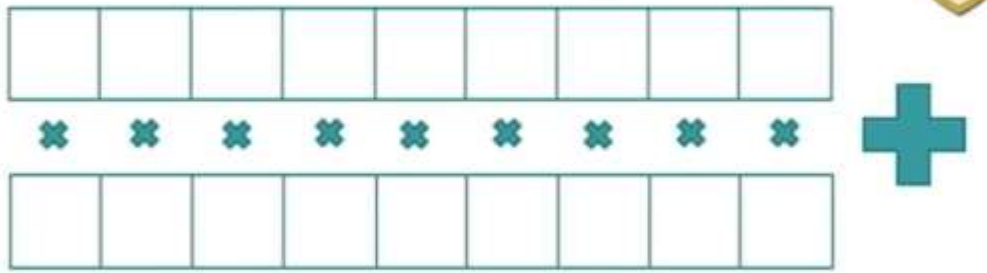


NUMERIC ALGORITHMS

count

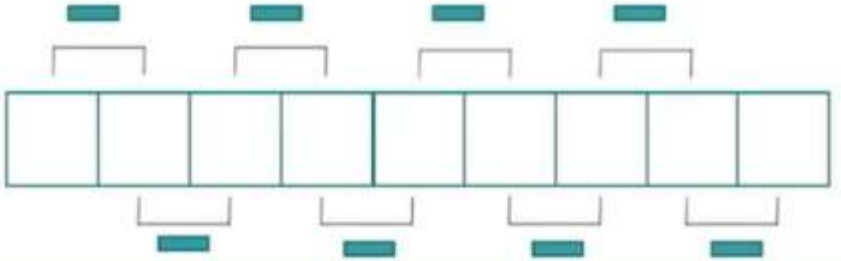


inner_product

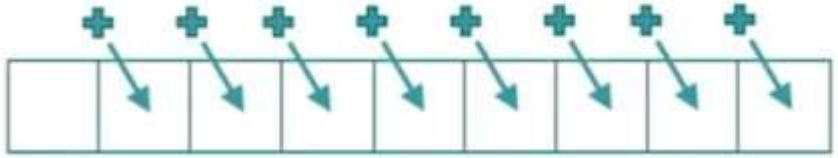


accumulate/(transform_)reduce

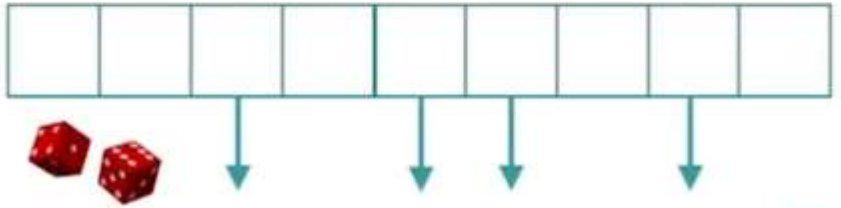
adjacent_difference



partial_sum
(transform_)inclusive_scan
(transform_)exclusive_scan



sample



accumulate	partial_sum
adjacent_difference	reduce
exclusive_scan	transform_exclusive_scan
inclusive_scan	transform_inclusive_scan
inner_product	transform_reduce
iota	

`partial_sum` applications

- Range sum
- Use with `binary_search`
- Lambda+

```cpp
vector v = { 1, 1, 1, 1, 1 };
vector u(5, 0);
partial_sum(cbegin(v), cend(v), begin(u));

// 1 2 3 4 5

vector v = { 1, 2, 3, 4, 5 };
vector u(5, 0);
partial_sum(cbegin(v), cend(v), begin(u));

// 1 3 6 10 15
```

```cpp
// map<int, int> queries;

vector v = { 1, 2, ... , 100 };
vector u(v.size(), 0);
partial_sum(cbegin(v), cend(v), begin(u));

for (auto [a, b] : queries) {
    auto sum = u[b] - u[a];
}
```

LeetCode

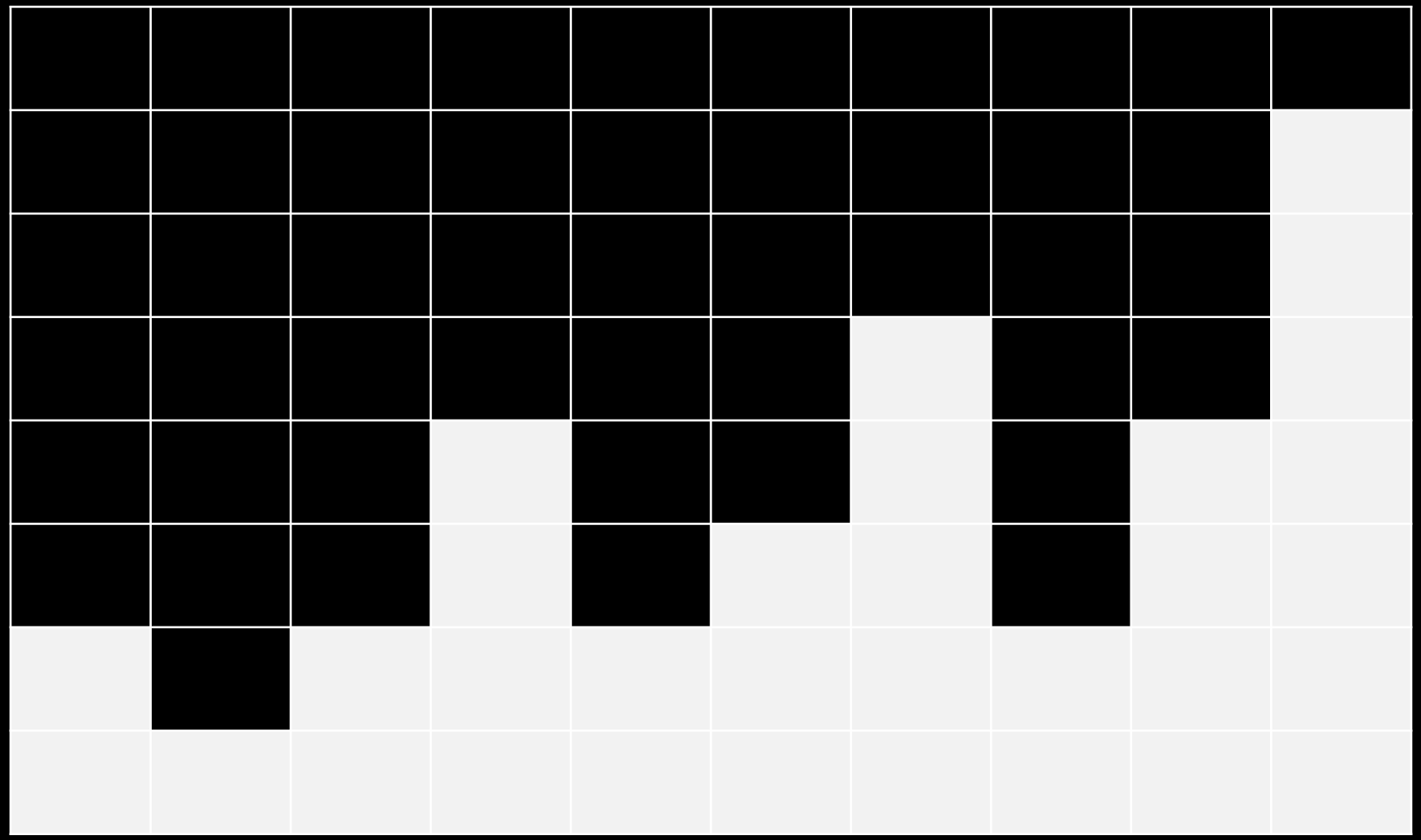
42. Trapping Rain Water

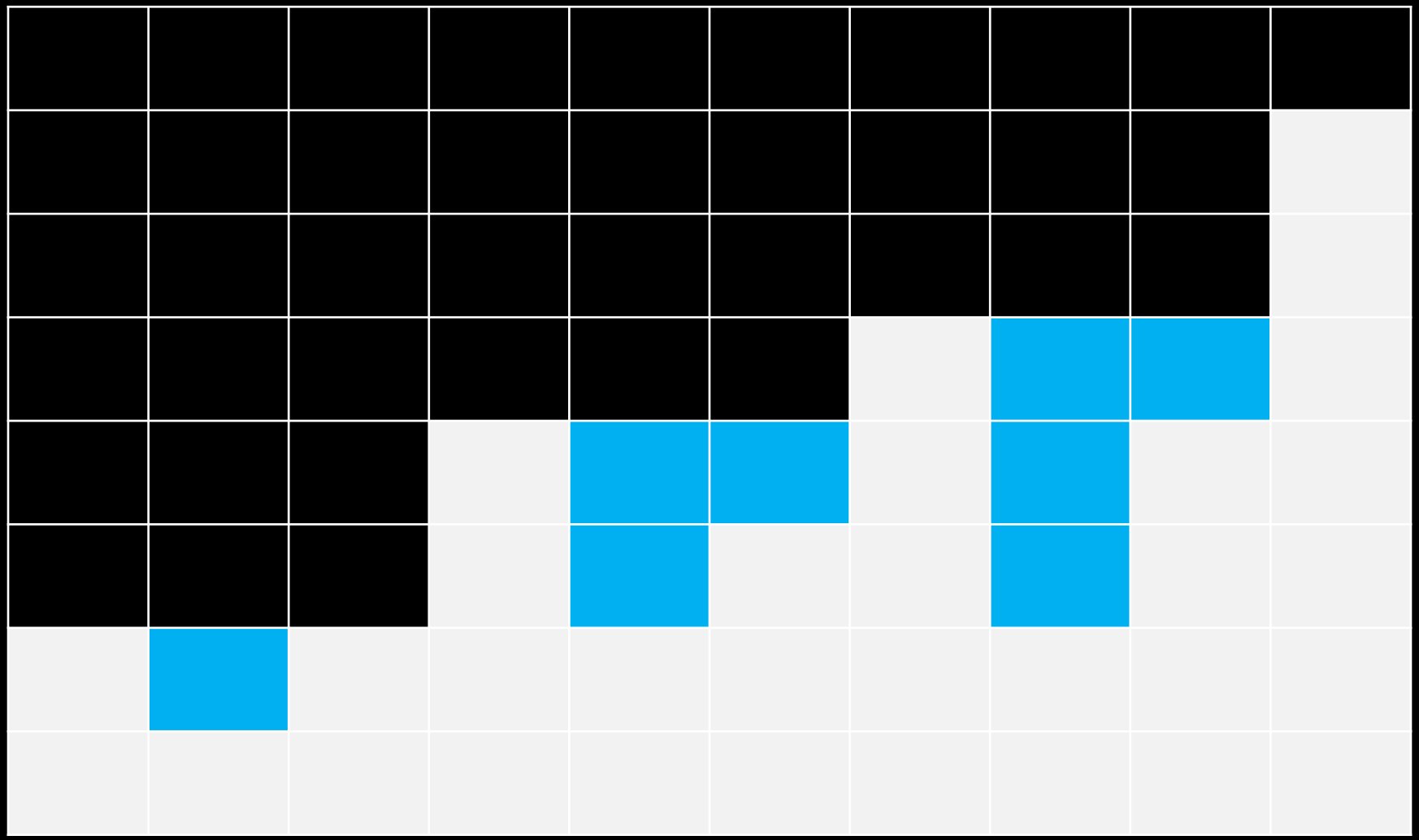
Hard 3387 61 Favorite Share

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!

https://leetcode.com/problems/trapping-rain-water/





```cpp
auto solve() {
    vector v = { 2, 1, 2, 4, 2, 3, 5, 2, 4, 7 };
    auto m   = v.front(); // max so far
    auto ans = 0;
    for (auto e : v) {
        m    = max(m, e);
        ans += m - e;
    }
    return ans;
}
```

```
auto solve() {
    vector v = { 2, 1, 2, 4, 2, 3, 5, 2, 4, 7 };
    vector u(v.size(), 0);
    partial_sum(cbegin(v), cend(v), begin(u),
        [](auto a, auto b) { return max(a, b); });
    return transform_reduce(cbegin(v), cend(v), cbegin(u), 0,
        std::plus{},
        [](auto a, auto b) { return abs(a - b); });
}
```

Not the best name …

```
auto solve() {
    vector v = { 2, 1, 2, 4, 2, 3, 5, 2, 4, 7 };
    vector u(v.size(), 0);
    partial_sum(cbegin(v), cend(v), begin(u), ufo::max{});
    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,
        std::plus{},
        std::minus{});
}
```

```
auto solve() {
    vector v = { 2, 1, 2, 4, 2, 3, 5, 2, 4, 7 };
    vector u(v.size(), 0);
    inclusive_scan(cbegin(v), cend(v), begin(u), ufo::max{});
    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,
        std::plus{},
        std::minus{});
}
```

LeetCode

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!

https://leetcode.com/problems/trapping-rain-water/

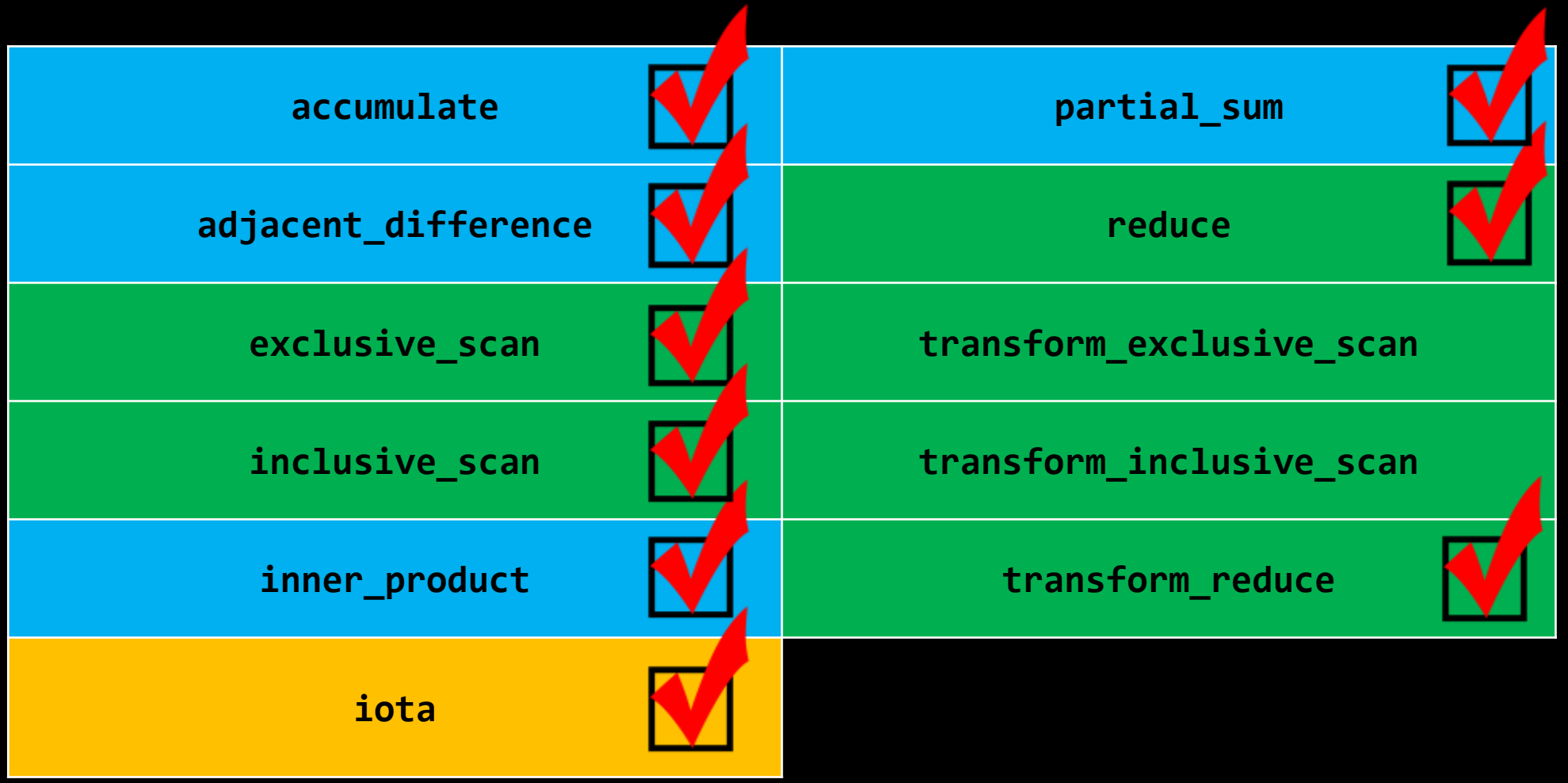
```cpp
int trap(vector<int>& v) {
    vector u(v.size(), 0);
    inclusive_scan(begin(v),  end(v),   begin(u),  ufo::max{});
    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,
        std::plus<>(),
        std::minus<>());
}
```

```cpp
int trap(vector<int>& v) {
    vector u(v.size(), 0);
    auto it = max_element(begin(v), end(v));
    inclusive_scan(begin(v),  end(v),   begin(u),  ufo::max{});
    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,
        std::plus<>(),
        std::minus<>());
}
```

```cpp
int trap(vector<int>& v) {
    vector u(v.size(), 0);
    auto it = max_element(begin(v), end(v));
    inclusive_scan(begin(v),  next(it), begin(u),  ufo::max{});
    return transform_reduce(cbegin(u), cend(u), cbegin(v), 0,
        std::plus<>(),
        std::minus<>());
}
```

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

```cpp
template<class T>
using rev = reverse_iterator<T>;

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



Pre-C++11	C++11	C++17

The Algorithm Intuition Table

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
iota	N / A	N / A	Transform

```cpp
template <class I, class T, class R, class M>
auto adjacent_reduce(I f, I l, T init, R r, M m) {
   return inner_product(f, --l, ++f, init, r, m);
}
```

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

Solving a Problem with

The Algorithm Intuition Table

CODEFORCES

Round 77: Problem A – Football

Petya loves football very much. One day, as he was watching a football match, he was writing the players' current positions on a piece of paper. To simplify the situation he depicted it as a string consisting of zeroes and ones. A zero corresponds to players of one team; a one corresponds to players of another team. If there are at least 7 players of some team standing one after another, then the situation is considered dangerous. For example, the situation 00100110111111101 is dangerous and 11110111011101 is not. You are given the current situation. Determine whether it is dangerous or not.

https://codeforces.com/contest/96/problem/A

Round 77: Problem A – Football

Given a string of 1s and 0s, return true if the longest (contiguous) substring of *equal* elements is greater than or equal to 7.

Examples

input
001001
output
NO

input
1000000001
output
YES

https://codeforces.com/contest/96/problem/A

```cpp
auto dangerous_team(const string& s) -> bool {
    auto max_players = 1, curr_players = 1;
    for (int i = 1; i < s.size(); ++i) {
        curr_players = s[i] == s[i - 1] ? ++curr_players : 1;
        max_players = max(max_players, temp);
    }
    return max_players >= 7;
}
```

https://codeforces.com/contest/96/problem/A

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

```cpp
auto dangerous_team(string const& s) -> bool {
   return adjacent_reduce(cbegin(s), cend(s),
      make_pair(1, 1),
      [](pair<int, int> acc, bool equal) {
         auto [max_player, curr_player] = acc;
         curr_player = equal ? ++curr_player : 1;
         return make_pair(max(max_player, curr_player), curr_player);
      },
      std::equal_to{}).first >= 7;
}
```

https://codeforces.com/contest/96/problem/A

```cpp
auto dangerous_team(string const& s) -> bool {
   return adjacent_reduce(cbegin(s), cend(s),
      make_pair(1, 1),
      [](pair<int, int> acc, bool equal) {
         auto [mp, cp] = acc;
         cp = equal ? ++cp : 1;
         return make_pair(max(mp, cp), cp);
      },
      std::equal_to{}).first >= 7;
}
```

https://codeforces.com/contest/96/problem/A

```
"001001"
["00","1","00","1"]
[2,1,2,1]
2
False
```

```haskell
dangerous_teams :: String -> Bool
dangerous_teams = (>=7)
                . maximum
                . map length
                . group
```

https://codeforces.com/contest/96/problem/A

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
	2	No	Reduce*
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
	1*	No	Transform
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
transform	1*	No	Transform
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
transform	1*	No	Transform
😀	1	No	Reduce*
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
transform	1*	No	Transform
find*	1	No	Reduce*
iota	N / A	N / A	Transform

```
auto generate_n_fibonacci(int n) {
    vector fib(n, 1);
    transform(cbegin(fib),
              cend  (fib) - 2,
              cbegin(fib) + 1,
              begin (fib) + 2,
              std::plus{});
    return fib;
}
```

```
auto generate_n_fibonacci(int n) {
    vector fib(n, 1);
    adjacent_difference(cbegin(fib),
                        cend  (fib) - 1,
                        begin (fib) + 1,
                        std::plus{});
    return fib;
}
```

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = **Specified**	Reduce
inner_product / transform_reduce	1*	Yes Init = **Specified**	Reduce
partial_sum / inclusive_scan	1	Yes Init = **First elem**	Transform
exclusive_scan	1	Yes Init = **Specified**	Transform
adjacent_difference	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
transform	1*	No	Transform
find*	1	No	Reduce*
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform
accumulate / reduce	1	Yes Init = Specified	Reduce
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform
exclusive_scan	1	Yes Init = Specified	Transform
adjacent_transform	2	No	Transform
adjacent_reduce	2	Yes	Reduce
adjacent_find*	2	No	Reduce*
transform	1*	No	Transform
find*	1	No	Reduce*
iota	N / A	N / A	Transform

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}
exclusive_scan	1	Yes Init = Specified	Transform	plus{}
adjacent_transform adjacent_difference	2	No	Transform	minus{}
adjacent_reduce	2	Yes	Reduce	-
adjacent_find*	2	No	Reduce*	equal_to{}
transform	1*	No	Transform	-
find*	1	No	Reduce*	-
iota	N / A	N / A	Transform	

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}
exclusive_scan	1	Yes Init = Specified	Transform	plus{}
adjacent_transform adjacent_difference	2	No	Transform	minus{}
adjacent_reduce	2	Yes	Reduce	-
adjacent_find*	2	No	Reduce*	equal_to{}
transform	1*	No	Transform	-
find*	1	No	Reduce*	-
iota	N / A	N / A	Transform	

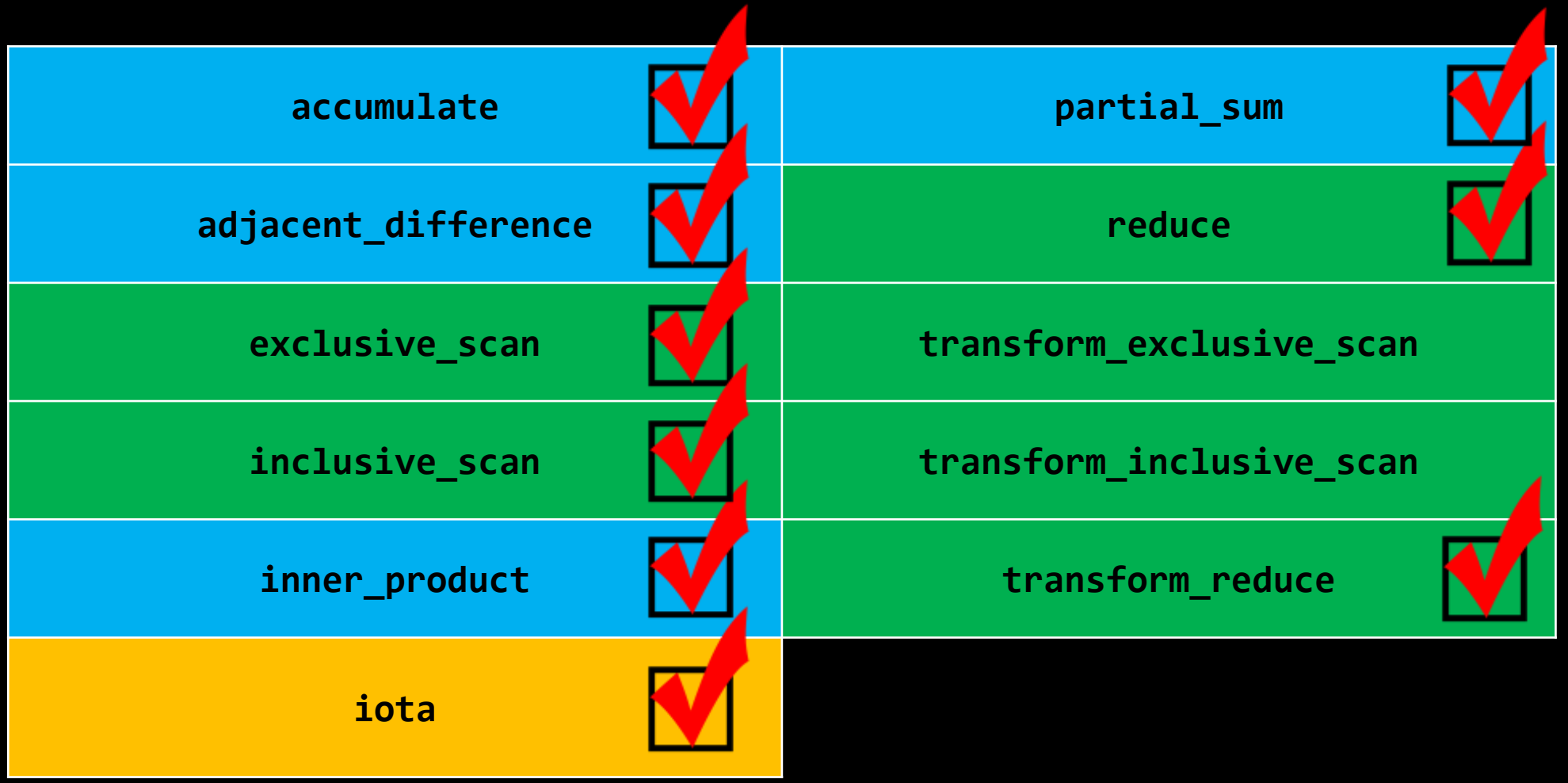
Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}
exclusive_scan	1	Yes Init = Specified	Transform	plus{}
adjacent_transform adjacent_difference	2	No	Transform	minus{}
😢	2	Yes	Transform	
adjacent_reduce	2	Yes	Reduce	-
adjacent_find*	2	No	Reduce*	equal_to{}
transform	1*	No	Transform	-
find*	1	No	Reduce*	-
iota	N / A	N / A	Transform	

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}
exclusive_scan	1	Yes Init = Specified	Transform	plus{}
adjacent_transform adjacent_difference	2	No	Transform	minus{}
adjacent_inclusive_scan	2	Yes	Transform	
adjacent_reduce	2	Yes	Reduce	-
adjacent_find*	2	No	Reduce*	equal_to{}
transform	1*	No	Transform	-
find*	1	No	Reduce*	-
iota	N / A	N / A	Transform	

```cpp
template<class I, class O, class BinOp1, class BinOp2>
auto adjacent_inclusive_scan(I f, I l, O o, BinOp1 binop1,
                                            BinOp2 binop2) {
   if (f != l) {
      auto prev = *f; // previous element
      auto acc  = *f; // accumulator
      *o = prev;      // first element special treatment
      while (++f != l) {
         acc = binop1(acc, binop2(*f, prev));
         *++o = acc;
         prev = std::move(*f);
      }
      ++o;
   }
   return o;
}
```

Does anyone know what is odd about this?

```
adjacent_inclusive_scan(cbegin(v),
                        cend(v),
                        begin(u),
                        std::plus(),
                        [](auto a, auto b) {
                            return a == b ? b : 0;
                        });
```



Pre-C++11	C++11	C++17

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}
exclusive_scan	1	Yes Init = Specified	Transform	plus{}
adjacent_transform adjacent_difference	2	No	Transform	minus{}
transform_inclusive_scan	2	Yes	Transform	-
adjacent_reduce	2	Yes	Reduce	-
adjacent_find*	2	No	Reduce*	equal_to{}
transform	1*	No	Transform	-
find*	1	No	Reduce*	-
iota	N / A	N / A	Transform	

Algorithm	Indexes Viewed	Accumulator	Reduce / Transform	Default Op	Filter aka _if
accumulate / reduce	1	Yes Init = Specified	Reduce	plus{}	
inner_product / transform_reduce	1*	Yes Init = Specified	Reduce	plus{}, mult{}	
partial_sum / inclusive_scan	1	Yes Init = First elem	Transform	plus{}	
exclusive_scan	1	Yes Init = Specified	Transform	plus{}	
adjacent_transform adjacent_difference	2	No	Transform	minus{}	
transform_inclusive_scan	2	Yes	Transform	-	
adjacent_reduce	2	Yes	Reduce	-	
adjacent_find*	2	No	Reduce*	equal_to{}	
transform	1*	No	Transform	-	
find*	1	No	Reduce*	-	
iota	N / A	N / A	Transform		

One last

https://i.stack.imgur.com/0kZO8.jpg

One last problem…

```
vector w = {1, 1, 2, 1, 1, 1, 1, 4, 3 };
vector t = {1, 1, 3, 1, 1, 1, 3, 1, 1 };
```


```
auto calc_word_score(vector<int> const& word,
                     vector<int> const& tile) -> int {
    return transform_reduce(cbegin(word),
                            cend(word),
                            cbegin(tile),
                            0);
}
```

Before we conclude …

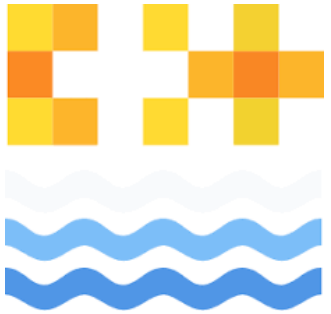
cppcon
the c++ conference

C++ now

Meeting C++

pacific++

accu
professionalism in programming



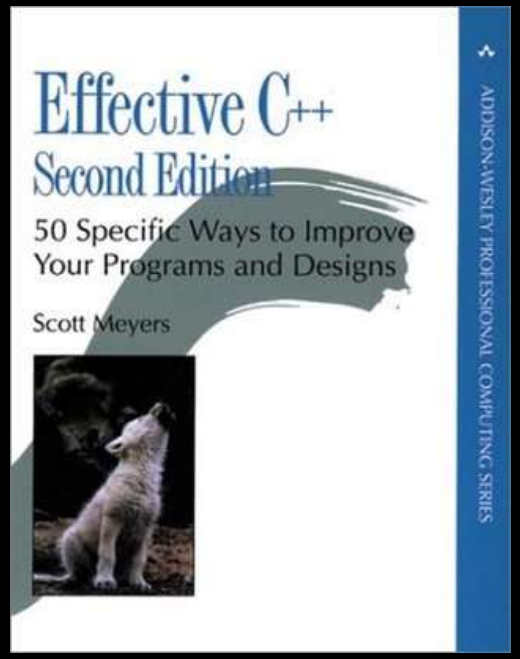

CppCast
auto CppCast = pod_cast<C++>("http://cppcast.com");


Cpp.chat


LAMBDA
CAST


Functional
Geekery

Read these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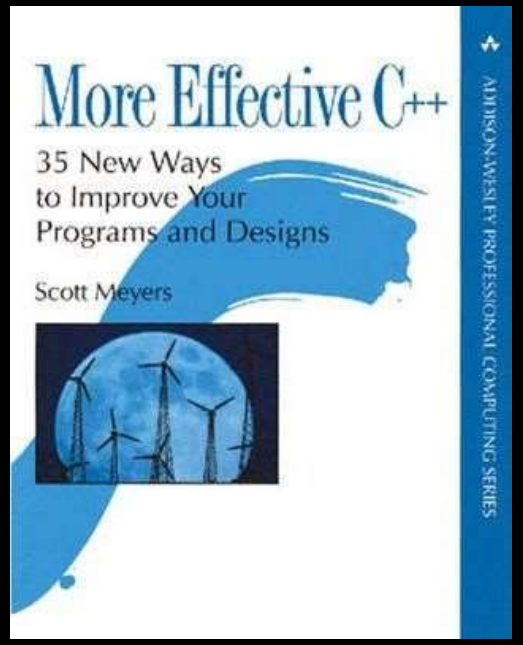
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Scott Meyers
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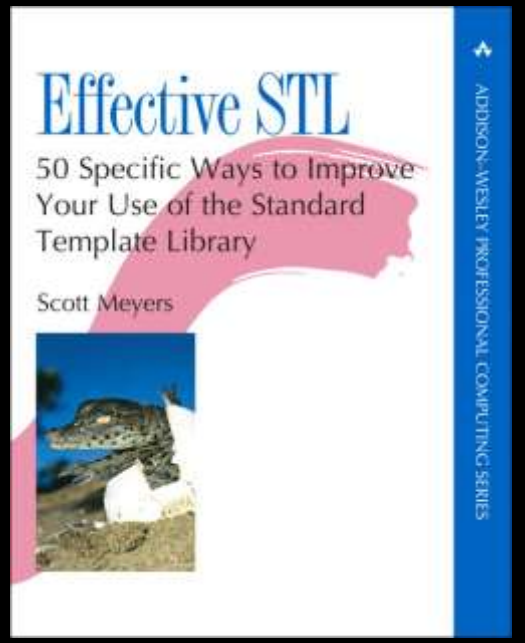
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Scott Meyers
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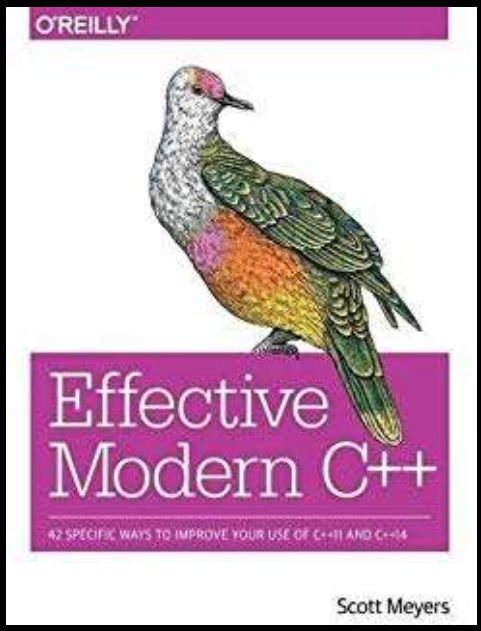
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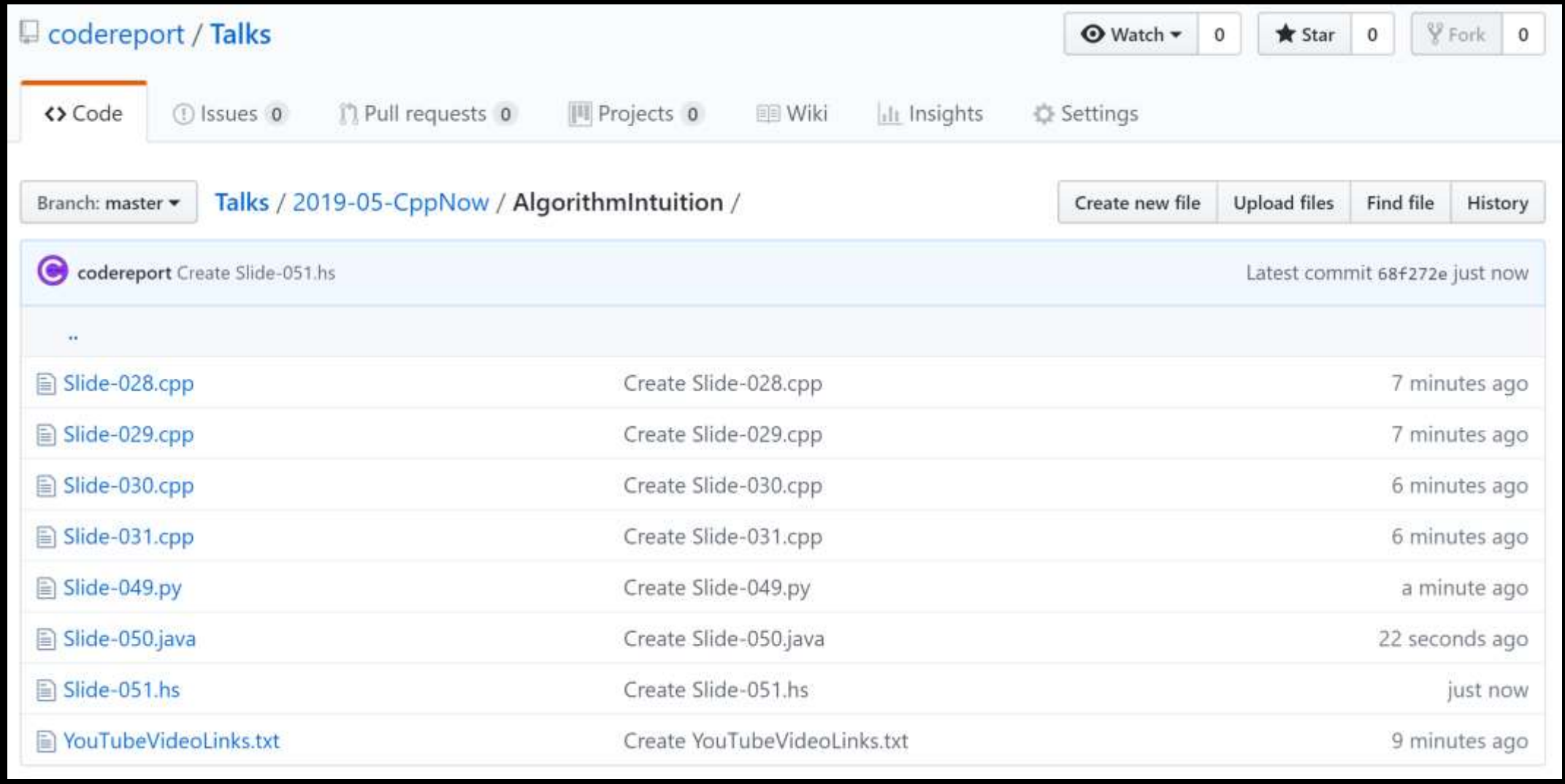
Effective Modern C++
Scott Meyers

code_report

codereport

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



Conclusion

1. Algorithms are awesome! And fun!
2. Especially `transform_reduce`
    1. `minmax_element, min_element, max_element, sort, iota, count_if, inner_product, adjacent_difference, partial_sum, accumulate, reduce, inclusive_scan, exclusive_scan`
3. Know the default operations that algorithms come with
4. Leverage algorithms with function objects / lambdas
5. C++20 ranges are going to (hopefully) give us composable algorithms

Thanks!

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

Conor Hoekstra

code_report

codereport

I would love feedback …

https://cppnow.dascandy.com/

Questions?

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

https://cppnow.dascandy.com/

Conor Hoekstra

code_report

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