Safe C++ @ O'Reilly

2. Safe C++

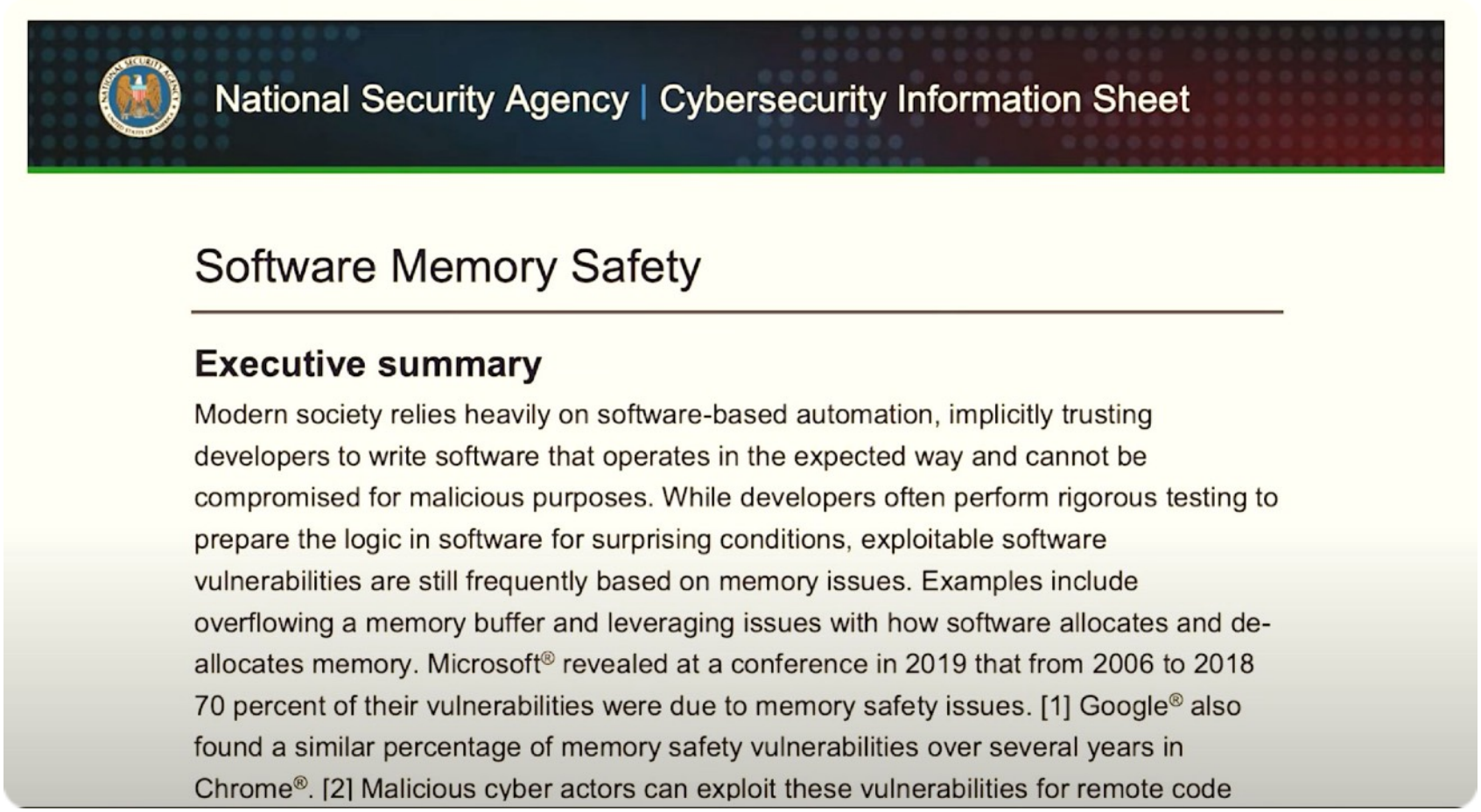
Klaus Iglberger
April, 22nd, 2025

Content

2.1. Motivation

C++ has a Problem

C++ has a Safety Problem



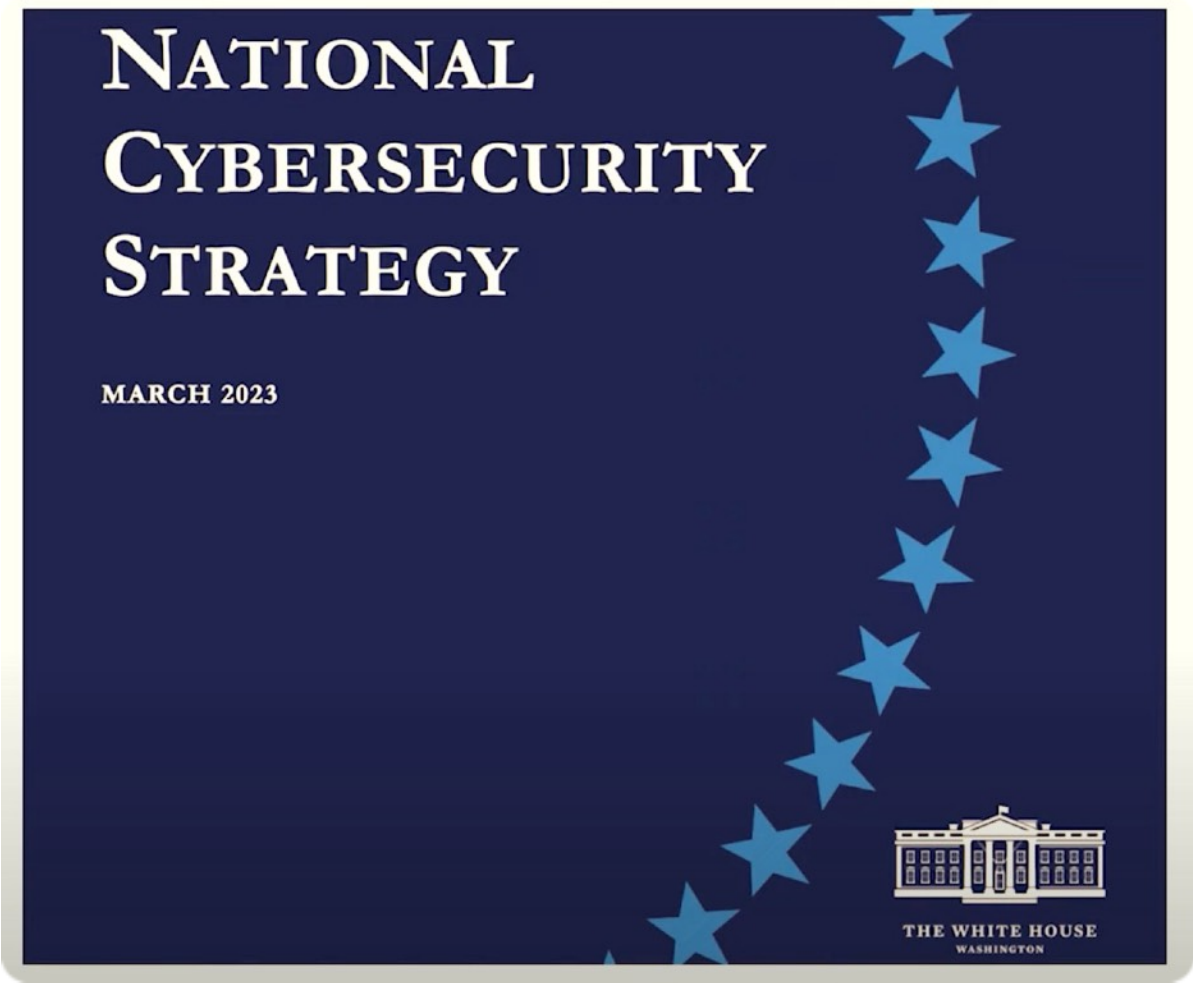
National Security Agency | Cybersecurity Information Sheet

Software Memory Safety

Executive summary

Modern society relies heavily on software-based automation, implicitly trusting developers to write software that operates in the expected way and cannot be compromised for malicious purposes. While developers often perform rigorous testing to prepare the logic in software for surprising conditions, exploitable software vulnerabilities are still frequently based on memory issues. Examples include overflowing a memory buffer and leveraging issues with how software allocates and de-allocates memory. Microsoft® revealed at a conference in 2019 that from 2006 to 2018 70 percent of their vulnerabilities were due to memory safety issues. [1] Google® also found a similar percentage of memory safety vulnerabilities over several years in Chrome®. [2] Malicious cyber actors can exploit these vulnerabilities for remote code

https://www.nsa.gov/Press-Room/News-Highlights/Article/Article/3215760/



https://www.whitehouse.gov/wp-content/uploads/2023/03/National-Cybersecurity-Strategy-2023.pdf

https://digital-strategy.ec.europa.eu/en/library/cyber-resilience-act

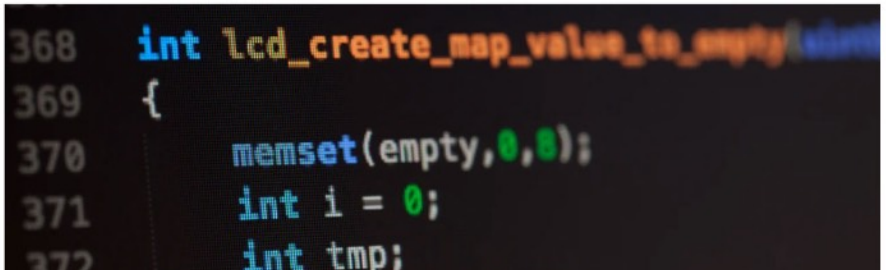
MOTHERBOARD
TECH BY VICE

The Internet Has a Huge C/C++ Problem and Developers Don't Want to Deal With It

What do Heartbleed, WannaCry, and million dollar iPhone bugs have in common?

AG By Alex Gaynor

November 15, 2018, 1:39pm Share Tweet Snap



https://www.vice.com/en/article/a3mgxb/the-internet-has-a-huge-cc-problem-and-developers-dont-want-to-deal-with-it

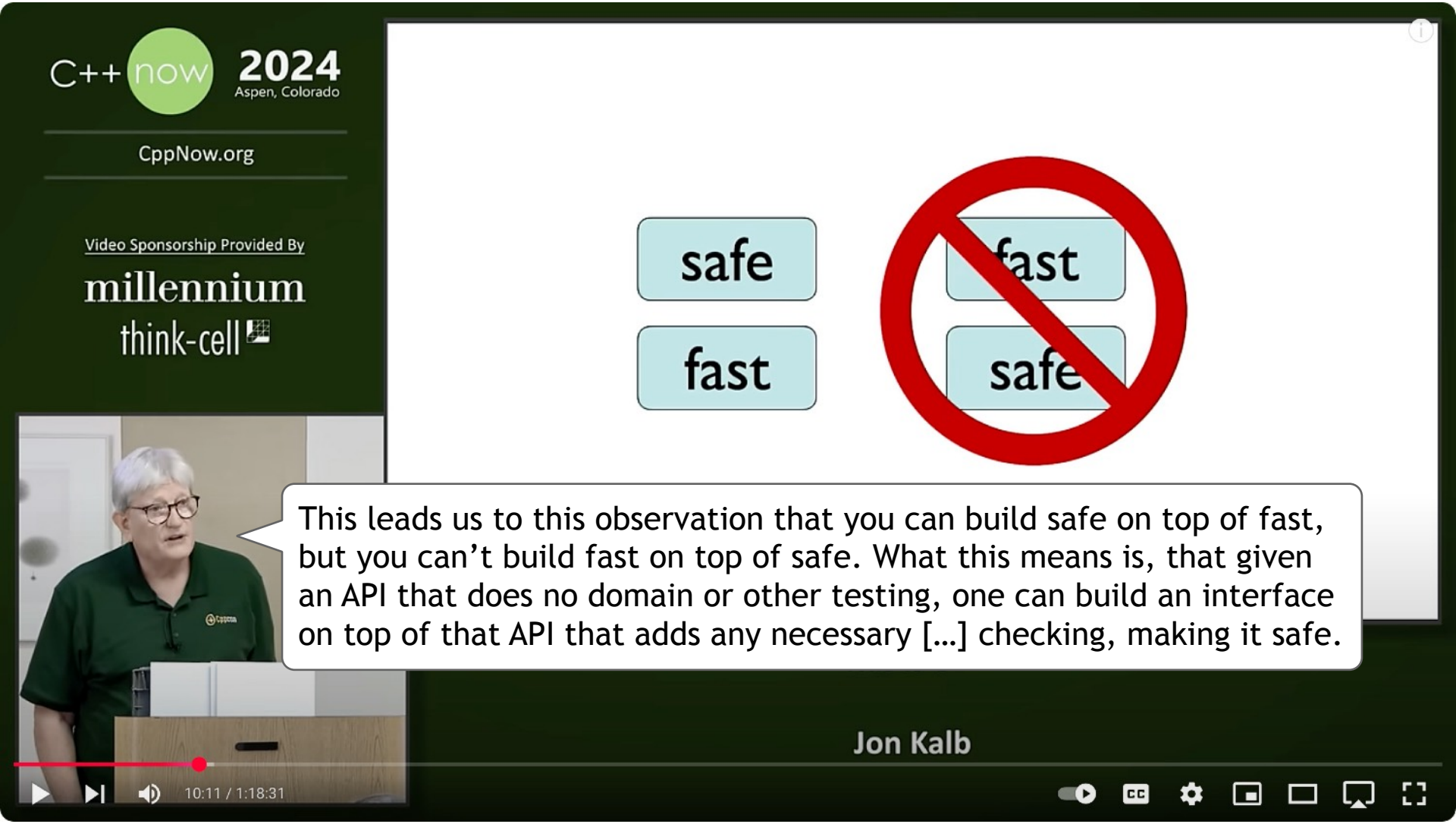
C++ has a Safety Problem?

Yes …

… if you still program in classic C++!

How did we get there?

https://www.youtube.com/watch?v=08gvuBC-MIE



https://www.youtube.com/watch?v=08gvuBC-MIE

Was this a bad Strategy?

Is C++ Broken?

No!

But we have to do our work

Yes, we have to continue to improve the language to make writing safe code simpler.

But there is an even more important task!

We have to communicate better how to program in C++!

Terminology: Safety vs. Security

”The immediate problem is that it’s Too Easy By Default™ to write security and safety vulnerabilities in C++ that would have been caught by stricter enforcement of known rules for Type, Bounds, Initialization, and Lifetime language safety”

(Herb Sutter)

Terminology: Safety vs. Security

”The immediate problem is that it’s Too Easy By Default™ to write security and safety vulnerabilities in C++ that would have been caught by stricter enforcement of known rules for Type, Bounds, Initialization, and Lifetime language safety”

(Herb Sutter)

The Four Horsemen of the Apocalypse art by theDURRRRIAN

The Four Horsemen of the Apocalypse art by theDURRRRIAN

2. Safe C++ – Motivation

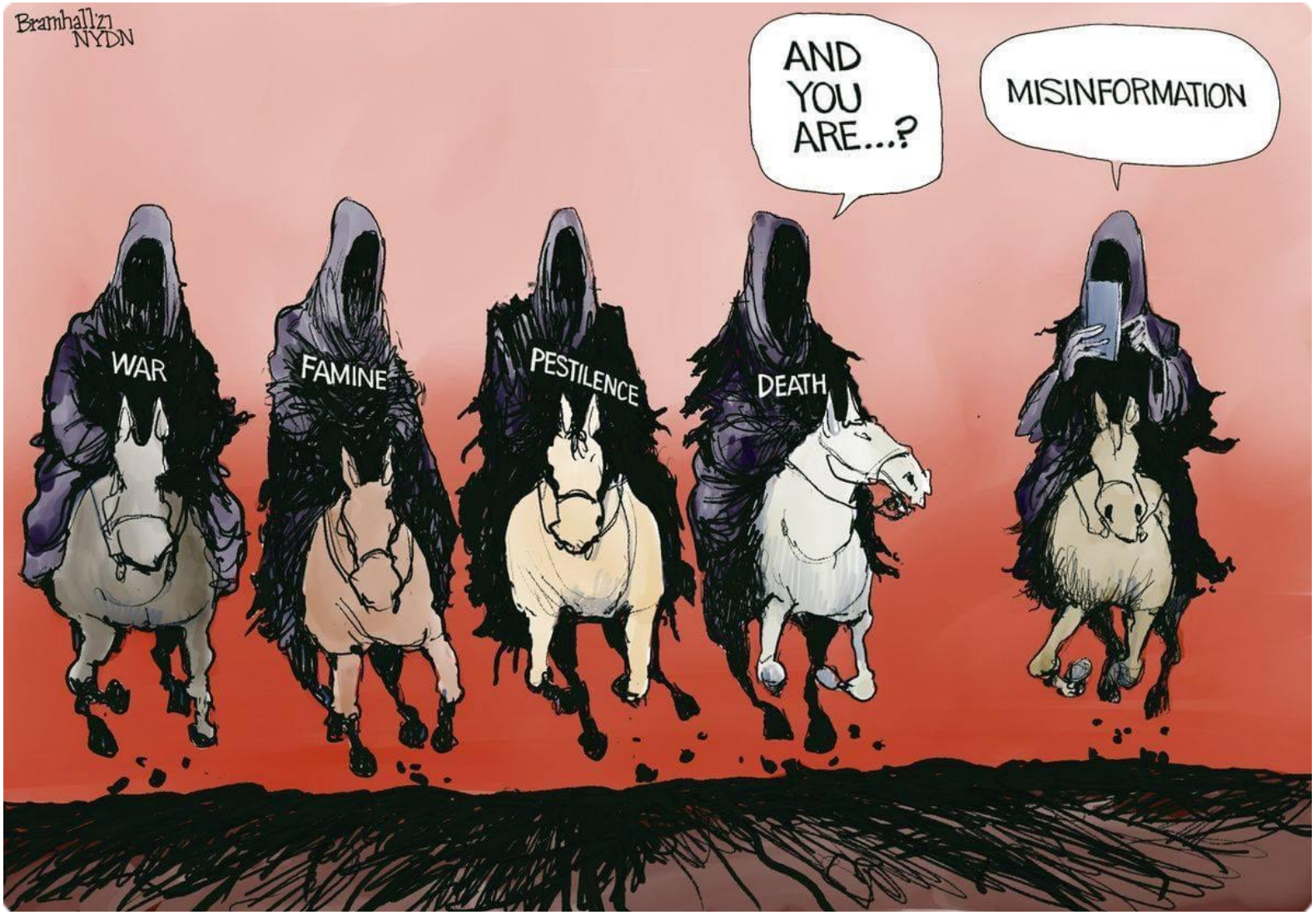


Illustration by Bill Bramhall from the New York Daily News

The Four Horsemen of the Apocalypse art by theDURRRRIAN

2.2. Undefined Behavior

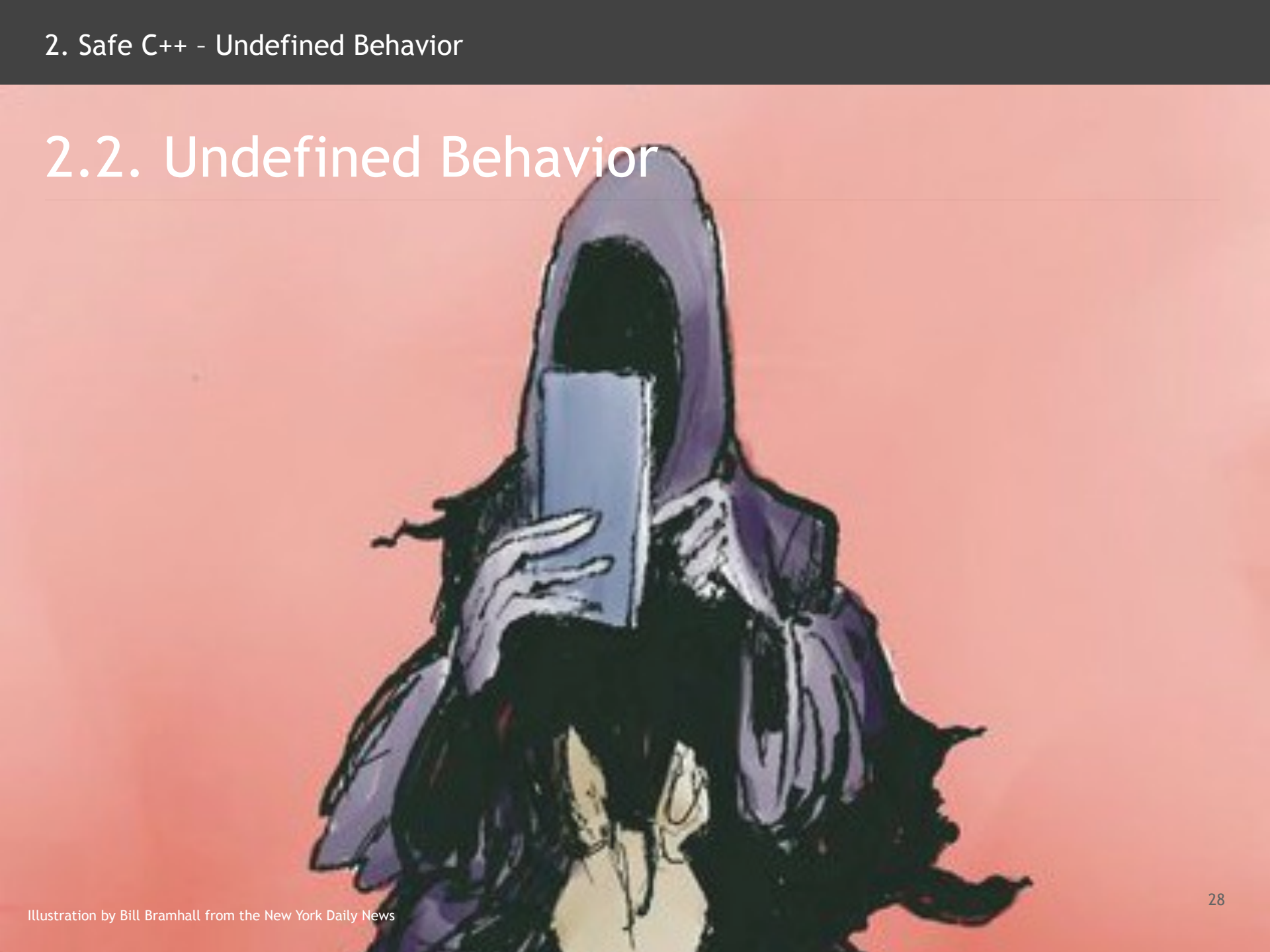


Illustration by Bill Bramhall from the New York Daily News

Programming Task

Task (3_Concepts_and_STL/constexpr/UniquePtr_constexpr): What is wrong with the following given `unique_ptr` class template? Try to find all flaws and think about how you would test the class to detect these flaws.

```
template< typename T >
class unique_ptr
{
 public:
   unique_ptr() {}
   unique_ptr( T* ptr ) : ptr_{ptr} {}

   T& operator*() const { return *ptr_; }
   T* get() const { return ptr_; }

 private:
   T* ptr_;
};
```

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

https://www.youtube.com/watch?v=PJwd4JLYJJY

https://www.youtube.com/watch?v=jAlFLEK3jiw

Programming Task

Task (3_Concepts_and_STL/constexpr/Count): Take a look at the given `count()` function. What is the expected result for the calls in the `main()` function?

```
std::uint64_t count( std::uint64_t size )
{
   std::uint64_t count{};

   for( int i=0; size-i >= 0; ++i ) {
      ++count;
   }

   return count;
}
```

Programming Task

Task (3_Concepts_and_STL/constexpr/IntegralShift): Take a look at the given `shift()` function. What is the expected result for the calls in the `main()` function?

```
std::uint64_t shift( std::uint64_t count )
{
   return 1 << (count % 64);
}
```

Guidelines

Core Guideline ES.100: Don’t mix signed and unsigned arithmetic

Core Guideline ES.101: Use unsigned types for bit manipulation

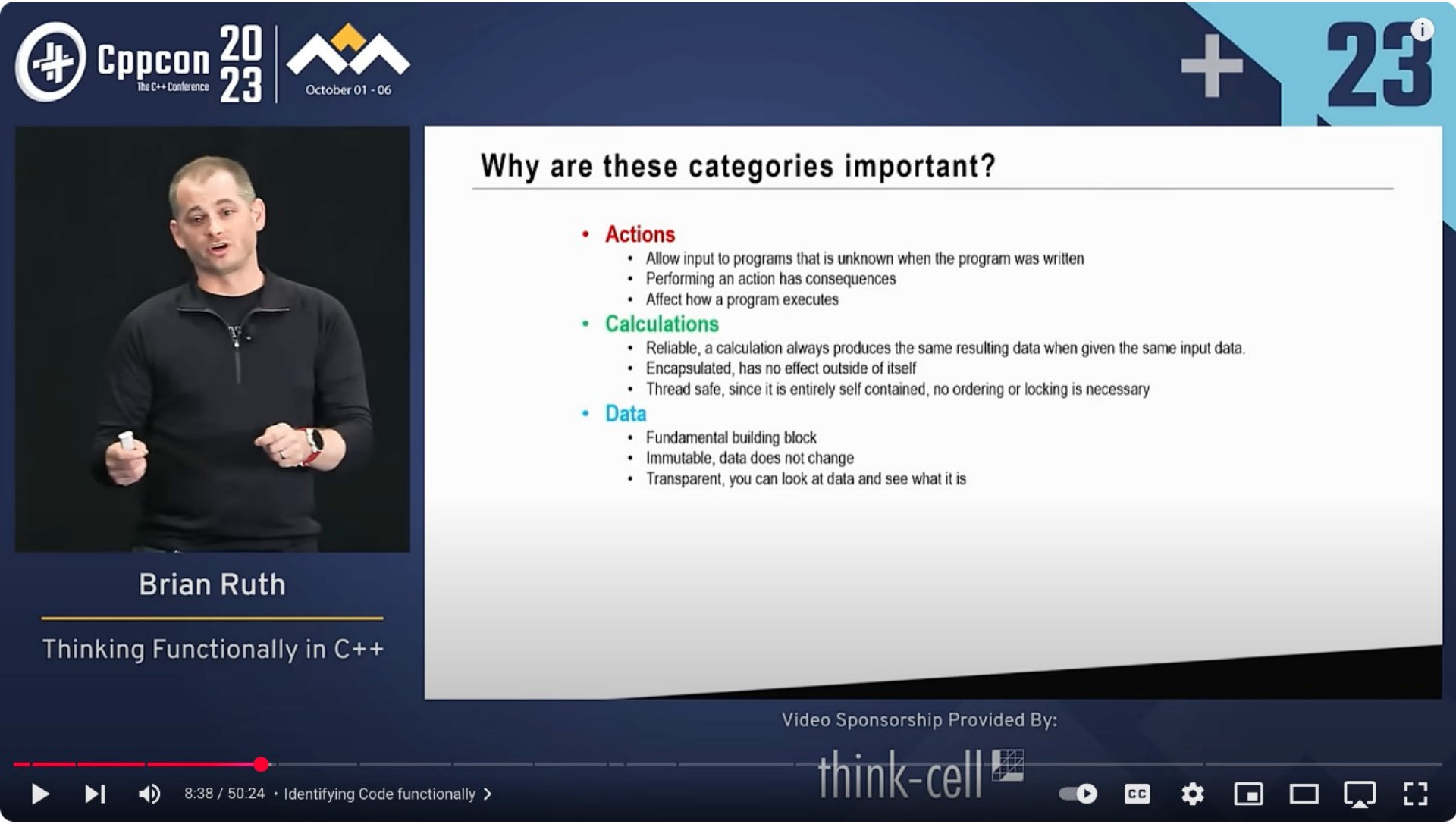
Core Guideline ES.102: Use signed types for arithmetic

I cannot add `constexpr` in front of every function. So much of our functionality is not `constexpr` yet and the compiler would constantly complain …

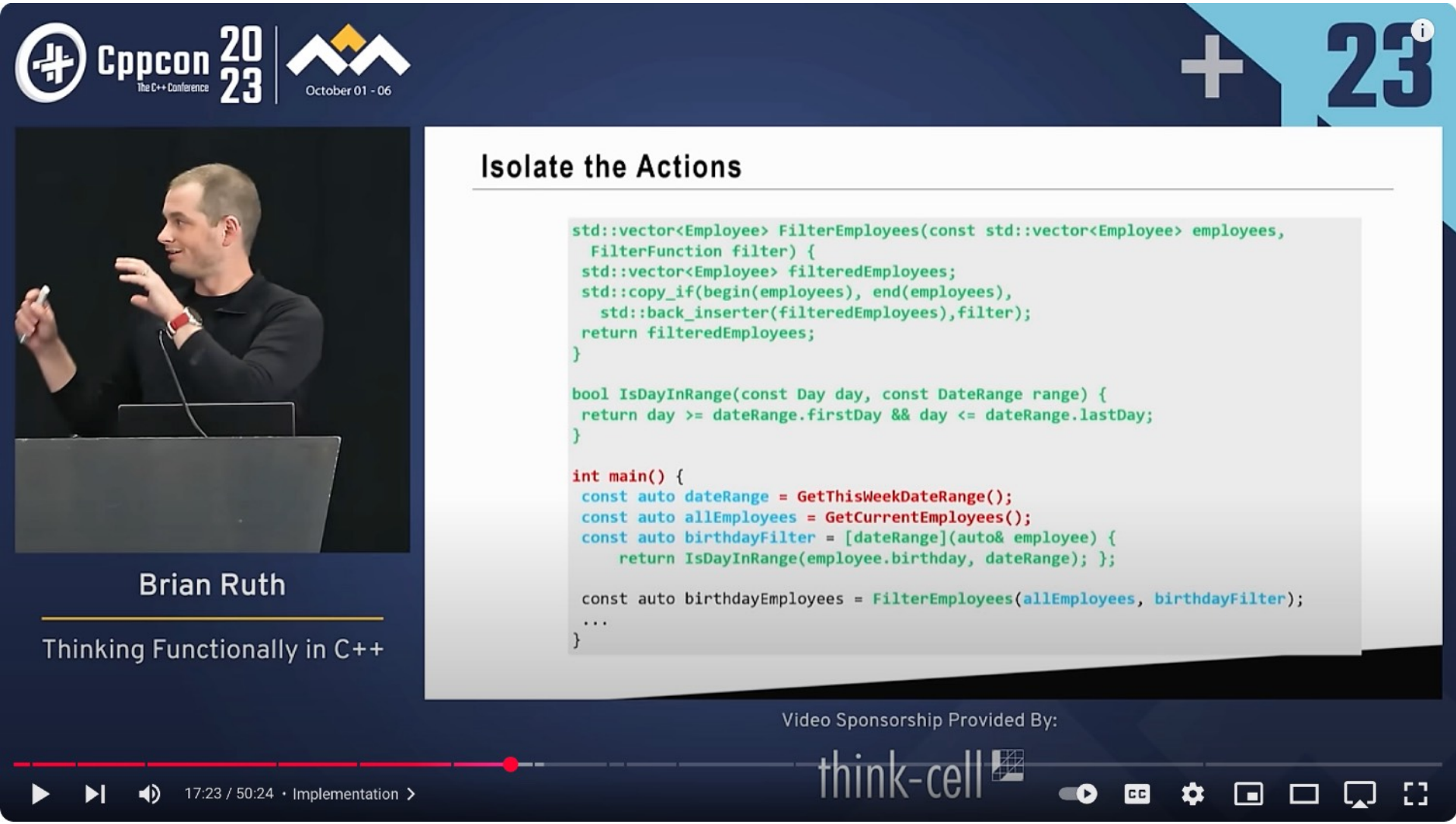
It’s all about the structure of your code. It’s all about the design.

Programming Task

Task (3_Concepts_and_STL/constexpr/Ranges_constexpr): What is wrong with the following given `print_countries()` function (think about changes in the input)? Try to find the flaw and think about how you would test the function to detect this flaw.



https://www.youtube.com/watch?v=6-WH9Hnec1M



https://www.youtube.com/watch?v=6-WH9Hnec1M

Guidelines

Guideline: Use `constexpr` whenever possible.

Guideline: Use `constexpr` in combination with compile time tests to avoid any undefined behavior.

Guideline: Separate your functionality into non-constexpr code that doesn't have to be tested (input, output, data, …) and `constexpr` code that can be tested at compile time.

2.3. Bounds Safety

Conquest and Glory by theDURRRRIAN

Programming Task

Task (2_Safe_Cpp/RangesRefactoring_Countries):

Step 1: Understand the code of the `main()` function: what does the final output print?

Step 2: Considering the general case, the initial code contains a bug. For which input does the given solution not work?

Step 3: Improve readability by choosing better names for the variables.

Step 4: Refactor the `main()` function from an imperative to a declarative style by means of C++20 ranges.

Bounds Safety Example

```
struct Country
{
   std::string name{};      // Name of the country
   std::string capital{};   // Name of the capital
   unsigned int area{};     // Area in square kilometer
   float residents{};       // Number of residents in millions
};


struct Continent
{
   std::string name{};                 // Name of the continent
   std::vector<Country> countries{};   // Countries of the continent
};


void print_five_biggest_countries()
{
   std::vector<Continent> continents = get_continents_with_countries();

   std::vector<Country> countries{};

   for( auto const& continent : continents ) {
      for( auto const& country : continent.countries )
```

Bounds Safety Example

```
struct Country
{
   std::string name{};      // Name of the country
   std::string capital{};   // Name of the capital
   unsigned int area{};     // Area in square kilometer
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Bounds Safety Example

```
void print_five_biggest_countries()
{
   std::vector<Continent> continents = get_continents_with_countries();

   std::vector<Country> countries{};

   for( auto const& continent : continents ) {
      for( auto const& country : continent.countries )
      {
         auto pos = begin(countries);

         while( pos != end(countries) && pos->area > country.area )
            ++pos;

         countries.insert( pos, country );
      }
   }

   std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

   for( size_t i=1U; i<5U; ++i )
   {
      auto& country1 = five_biggest_countries[i-1U];
      for( size_t j=i; j<5U; ++j ) {
         auto& country2 = five_biggest_countries[j];
         if( country1.residents < country2.residents ) {
```

Bounds Safety Example

```
void print_five_biggest_countries()
{
   std::vector<Continent> continents = get_continents_with_countries();

   std::vector<Country> countries{};

   for( auto const& continent : continents ) {
      for( auto const& country : continent.countries )
      {
         auto pos = begin(countries);

         while( pos != end(countries) && pos->area > country.area )
            ++pos;

         countries.insert( pos, country );
      }
   }

   std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

   for( size_t i=1U; i<5U; ++i )
   {
      auto& country1 = five_biggest_countries[i-1U];
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         if( country1.residents < country2.residents ) {
```

Bounds Safety Example

```
void print_five_biggest_countries()
{
   std::vector<Continent> continents = get_continents_with_countries();

   std::vector<Country> countries{};

   for( auto const& continent : continents ) {
      for( auto const& country : continent.countries )
      {
         auto pos = begin(countries);

         while( pos != end(countries) && pos->area > country.area )
            ++pos;

         countries.insert( pos, country );
      }
   }

   std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

   for( size_t i=1U; i<5U; ++i )
   {
      auto& country1 = five_biggest_countries[i-1U];
      for( size_t j=i; j<5U; ++j ) {
         auto& country2 = five_biggest_countries[j];
         if( country1.residents < country2.residents ) {
```

Bounds Safety Example

```
            countries.insert( pos, country );
         }
      }

      std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

      for( size_t i=1U; i<5U; ++i )
      {
         auto& country1 = five_biggest_countries[i-1U];
         for( size_t j=i; j<5U; ++j ) {
            auto& country2 = five_biggest_countries[j];
            if( country1.residents < country2.residents ) {
               Country tmp{ country1 };
               country1 = country2;
               country2 = tmp;
            }
         }
      }

      for( auto const& country : five_biggest_countries ) {
         std::cout << country << '\n';
      }
   }
```

Bounds Safety Example

```
            countries.insert( pos, country );
         }
      }

      std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

      for( size_t i=1U; i<5U; ++i )
      {
         auto& country1 = five_biggest_countries[i-1U];
         for( size_t j=i; j<5U; ++j ) {
            auto& country2 = five_biggest_countries[j];
            if( country1.residents < country2.residents ) {
               Country tmp{ country1 };
               country1 = country2;
               country2 = tmp;
            }
         }
      }

      for( auto const& country : five_biggest_countries ) {
         std::cout << country << '\n';
      }
   }
```

Bounds Safety Example

```
            countries.insert( pos, country );
        }
    }

    std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

    for( size_t i=1U; i<5U; ++i )
    {
        auto& country1 = five_biggest_countries[i-1U];
        for( size_t j=i; j<5U; ++j ) {
            auto& country2 = five_biggest_countries[j];
            if( country1.residents < country2.residents ) {
                Country tmp{ country1 };
                country1 = country2;
                country2 = tmp;
            }
        }
    }

    for( auto const& country : five_biggest_countries ) {
        std::cout << country << '\n';
    }
}
```

The UB smiley

Bounds Safety Example

```
            countries.insert( pos, country );
         }
      }

      assert( countries.size() >= 5U );  // The minimum number of countries must be 5!

      std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

      for( size_t i=1U; i<5U; ++i )
      {
         auto& country1 = five_biggest_countries[i-1U];
         for( size_t j=i; j<5U; ++j ) {
            auto& country2 = five_biggest_countries[j];
            if( country1.residents < country2.residents ) {
               Country tmp{ country1 };
               country1 = country2;
               country2 = tmp;
            }
         }
      }

      for( auto const& country : five_biggest_countries ) {
         std::cout << country << '\n';
      }
   }
```

Programming Task

Task (2_Safe_Cpp/RangesRefactoring_Birthday):

Step 1: Understand the inner workings of the `select_birthday_children()` function: what does the function return?

Step 2: Refactor the function from an imperative to a declarative style by means of C++20 ranges.

Step 3: Compare the runtime performance of both versions (imperative and declarative).

Programming Task

Task (2_Safe_Cpp/RangesRefactoring_Animals):

Step 1: Understand the code of the `main()` function: what does the final output print?

Step 2: Improve readability by choosing better names for the variables.

Step 3: Refactor the `main()` function from an imperative to a declarative style by means of C++20 ranges.

Programming Task

Task (2_Safe_Cpp/RangesRefactoring_Recipes):

Step 1: Understand the code of the `main()` function: what does the final output print?

Step 2: Refactor the `main()` function from an imperative to a declarative style by means of C++20/23 ranges.

Programming Task

Task (2_Safe_Cpp/Erase): Consider the given `std::vector<int>`. Remove all odd elements from the vector as efficiently as possible.

https://www.youtube.com/watch?v=08gvuBC-MIE

The Expert's Opinion

"If you want to improve code quality in your organization, I would say, take all your coding guidelines and replace them with the one goal. That's how important I think this one goal is:

No Raw Loops.

This will make the biggest change in code quality within your organization."

(Sean Parent, C++ Seasoning, Going Native 2013)

The Definition of Raw Loops

- A raw loop is any loop inside a function where the function serves purpose larger than the algorithm implemented by the loop.
- Range-based for loops for for-each and simple transforms
  - Use `auto const&` for for-each and `auto&` for transforms

```
for( auto const& elem : range ) f(elem);  // for-each
for( auto& elem : range ) e = f(elem);    // simple transform
```

  - Keep the body short

```
for( auto const& elem : range ) f(g(elem));
for( auto const& elem : range ) { f(elem); g(elem); }
for( auto& elem : range ) e = f(e) + g(e);
```

The Expert's Interpretation of Raw Loops

"9 times out of 10, a for-loop should either be the only code in a function, or the only code in the loop should be a function (or both)."

(Tony Van Eerd, @tvaneerd via Twitter)

The Expert's Opinion On The Cost of Code

"Each line of code costs a little. The more code you write, the higher the cost. The longer a line of code lives, the higher its cost. Clearly, unnecessary code needs to meet a timely demise before it bankrupts us."

(Pete Goodliffe, Becoming a Better Programmer)

The Expert's Opinion On Complexity

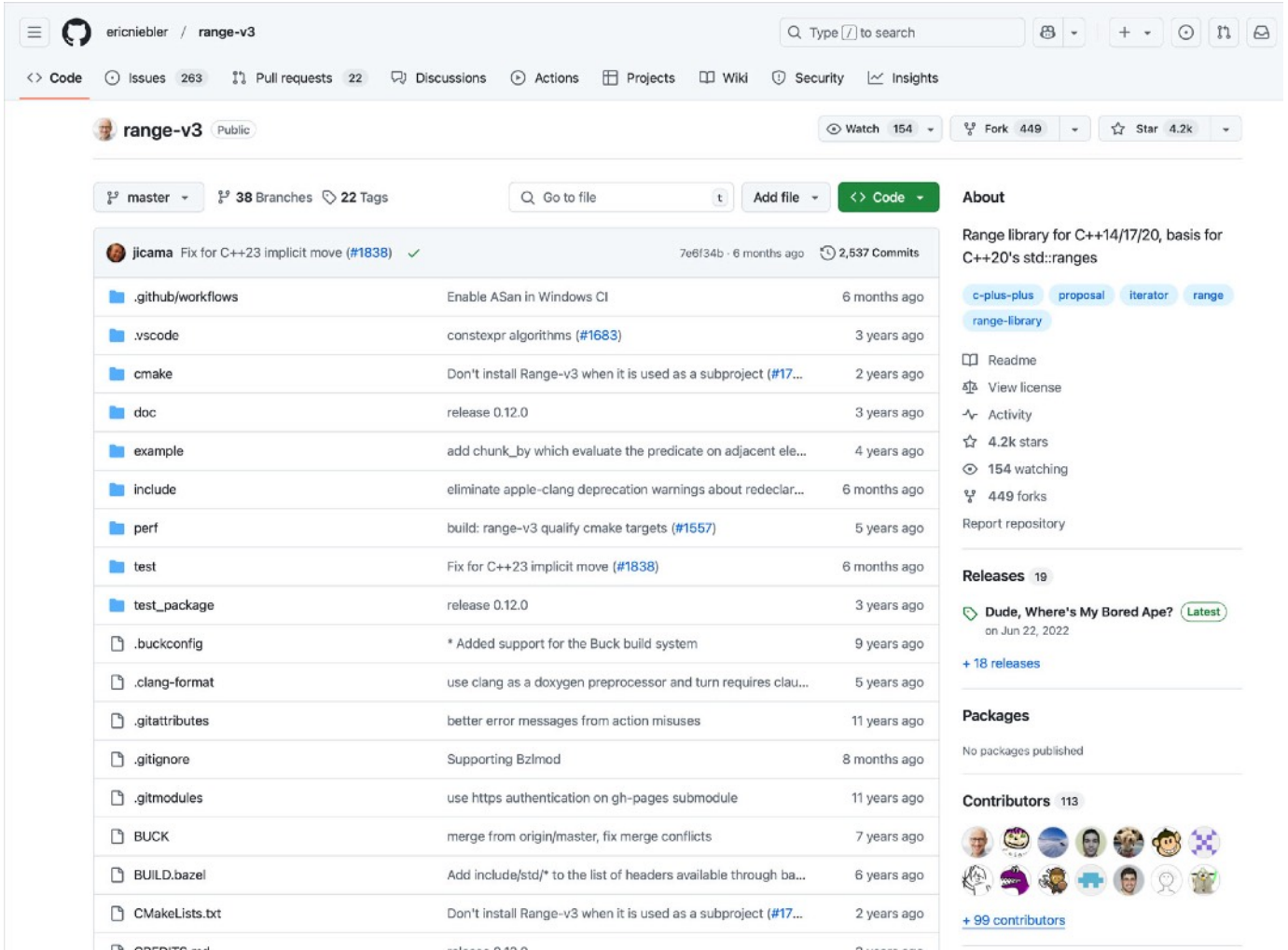
"Debugging is twice as hard as writing the code in the first place. Therefore, if you write the code as cleverly as possible, you are by definition, not smart enough to debug it."

(Brian Kernighan)

I cannot use C++20 yet.
Thus I cannot use ranges.

THE Ranges Library: ranges_v3

https://github.com/ericniebler/range-v3



Guidelines

Guideline: Manual loops are the biggest source of bounds safety issues. Using algorithms and C++20/23 ranges avoids this problem.

Guideline: Use algorithms to reduce the complexity of code.

Guideline: “No raw loops” (Sean Parent)

Guideline: Keep your code simple (KISS).

2.4. Type Safety

War and Ruin by theDURRRRIAN

Guidelines

Core Guideline I.4: Make interfaces precisely and strongly typed

The Expert's Opinion

"Make your interfaces easy to use correctly and hard to use incorrectly."

(Scott Meyers, Effective C++)

Type Safety: An Example

```
void extrapolate_position(
   double& x, double& y, double t,
   double vx, double vy,
   double ax=0.0, double ay=0.0 );

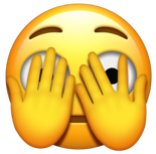

int main()
{
   // ...
   double x =  1.1;
   double y = -2.3;
   double time = 2.0;

   extrapolate_position( x, y, time, -0.43, -0.11 );

   extrapolate_position( x, y, -0.43, -0.11, time, 0.01 );
   // ...
}
```

It's sooo easy to swap values!

I cannot remember more than 5 parameters.



No info about expected units?

It returns via mutable references?

Type Safety: An Example

```
void extrapolate_position(
   double& x, double& y, double t,
   double vx, double vy,
   double ax=0.0, double ay=0.0 );


int main()
{
   // ...
   double x =  1.1;
   double y = -2.3;
   double time = 2.0;

   extrapolate_position( x, y, time, -0.43, -0.11 );

   extrapolate_position( x, y, -0.43, -0.11, time, 0.01 );
   // ...
}
```

This is not up-to-date C++ …

Type Safety: An Example

```
void extrapolate_position(
   double& x, double& y, double t,
   double vx, double vy,
   double ax=0.0, double ay=0.0 );


int main()
{
   // ...
   double x =  1.1;
   double y = -2.3;
   double time = 2.0;

   extrapolate_position( x, y, time, -0.43, -0.11 );

   extrapolate_position( x, y, -0.43, -0.11, time, 0.01 );
   // ...
}
```

… and it never was! …

Type Safety: An Improved Example

```
Position extrapolate_position(
   Position pos, Second time,
   MeterPerSecond velocity,
   MeterPerSquareSecond acceleration={} );


int main()
{
   // ...
   Position position{ 1.1, -2.3 };
   Second time{ 2.0 };
   MeterPerSecond velocity{ -0.43, -0.11 };

   extrapolate_position( position, time, velocity );

   extrapolate_position( position, time, velocity, Acceleration{0.01,0.0} );
   // ...
}
```

… Since C++98 we utilize strong types.

Guidelines

Core Guideline I.24: Avoid adjacent parameters of the same type when changing the argument order would change meaning

Guideline: Prefer strong types to integral and floating point parameters.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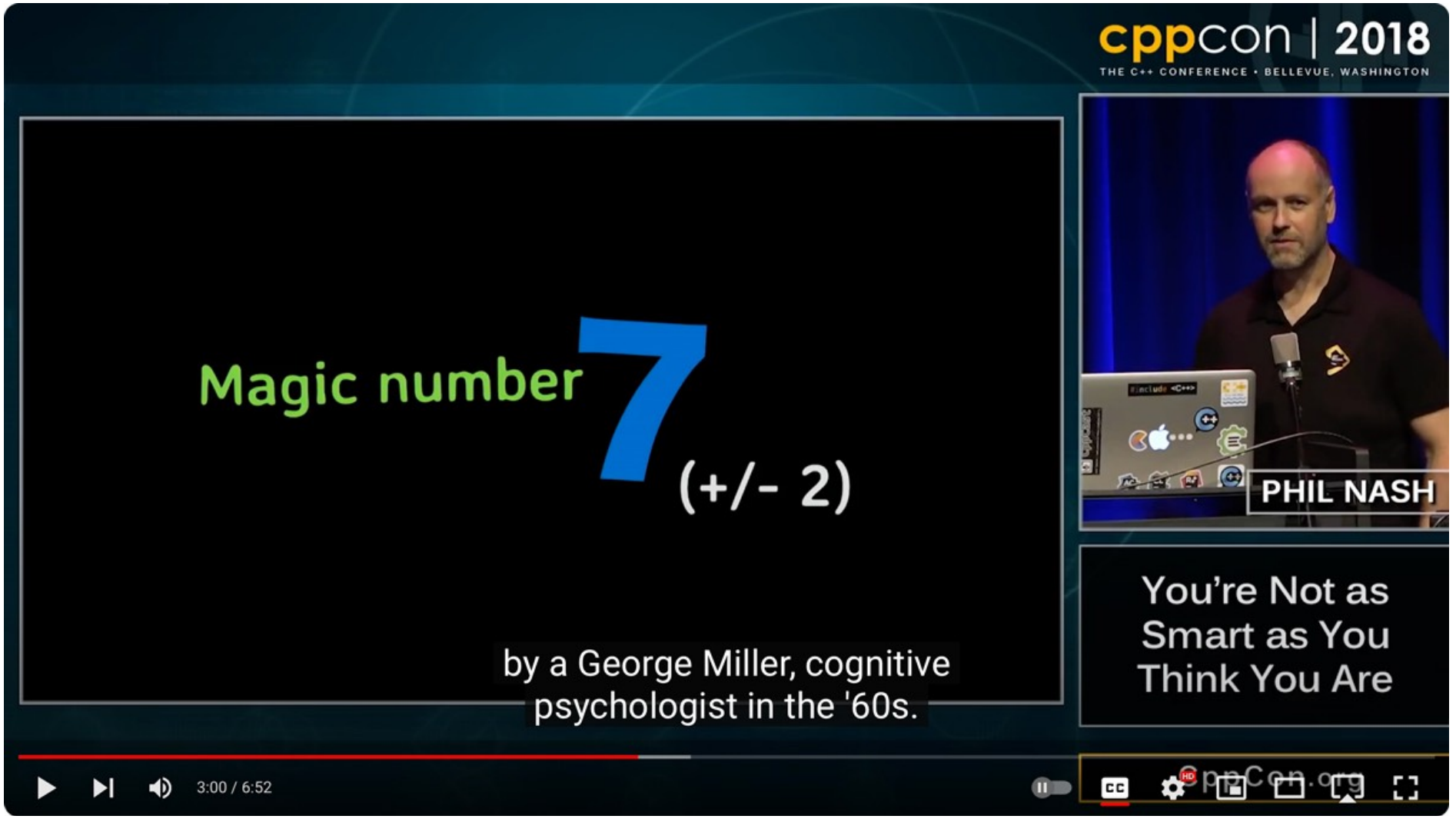
You Think You Are
- You are not as smart
as you think you are,
Presenter: Phil Nash
Play (k)
0:00 / 6:52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Magic number 7 (+/- 2)
by a George Miller, cognitive psychologist in the '60s.
PHIL NASH
You're Not as Smart as You Think You Are
3:00 / 6:52
CC
HD
cppcon.org

Guidelines

Core Guideline I.23: Keep the number of function arguments low

Guideline: Prefer a maximum of five function parameters.

Guidelines

Core Guideline I.4: Make interfaces precisely and strongly typed

Solution: Strong Types

Task (2_Safe_Cpp/Meter): Consider the `Meter` class that serve as a wrapper around integral values.

Step 1: What do we need to improve to really make this a strong type?

Step 2: Define user-defined literals for the `Meter` type.

Programming Task

Task (2_Safe_Cpp/Meter_Assembly): Compare the assembly output of the two functions `test()` (for instance by means of Compiler Explorer; godbolt.org). Is there any difference/overhead when using the `Meter` class template instead of the fundamental type?

Programming Task

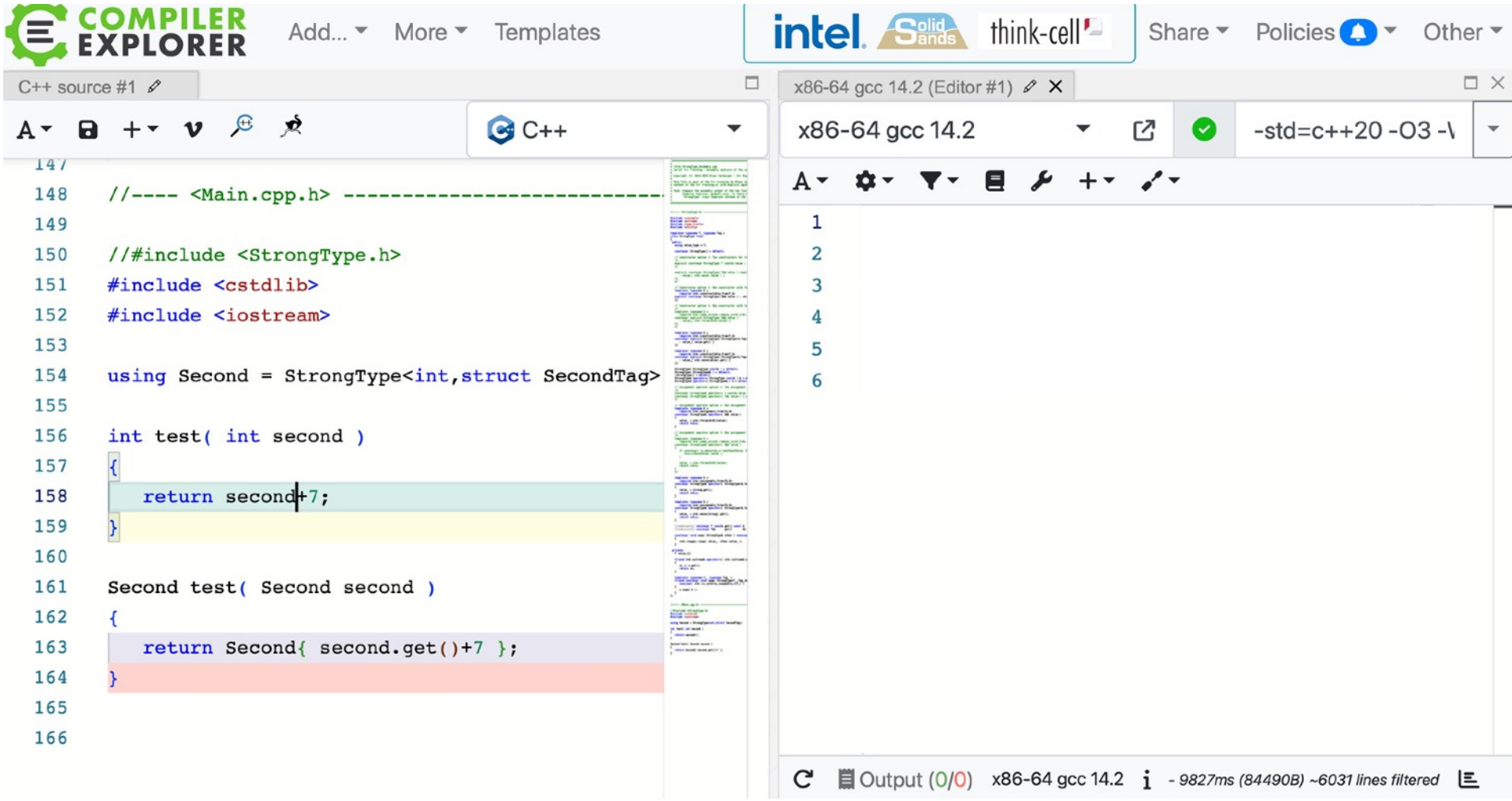
Task (2_Safe_Cpp/StrongType): Refactor the following code by means of strong types and according user-defined literals.

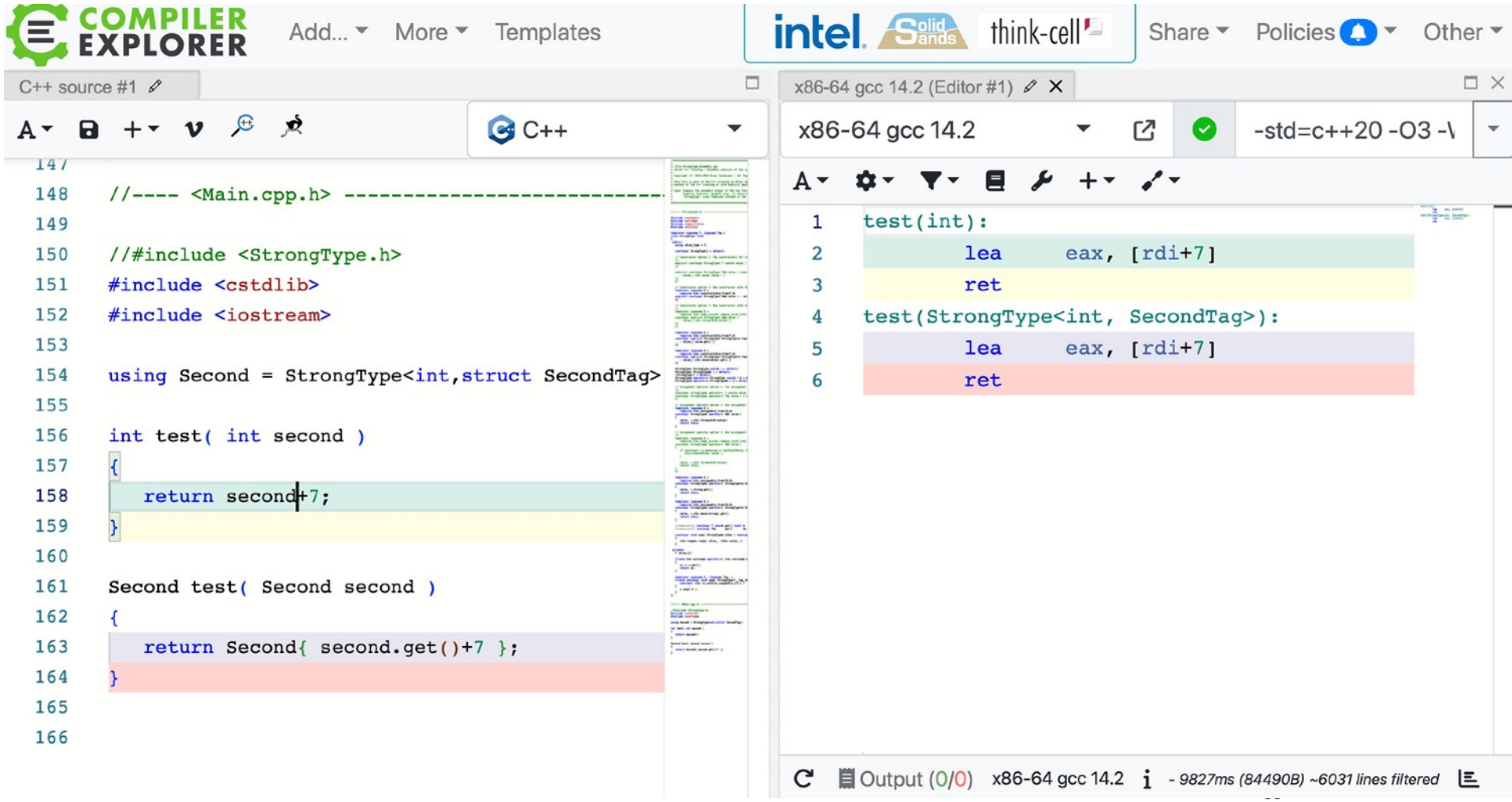
Programming Task

Task (2_Safe_Cpp/StrongType_Assembly): Compare the assembly output of the two functions test() (for instance by means of Compiler Explorer; godbolt.org). Is there any difference/overhead when using the `StrongType` class template instead of the fundamental type?

But what about performance? Aren't abstractions slow?

2. Safe C++ – Type Safety




COMPILER EXPLORER
Add...
More
Templates
intel
Solid Sands
think-cell
Share
Policies
Other
C++ source #1
C++
x86-64 gcc 14.2 (Editor #1)
x86-64 gcc 14.2
-std=c++20 -O3 -\
//---- <Main.cpp.h> ----------
//#include <StrongType.h>
#include <cstdlib>
#include <iostream>
using Second = StrongType<int,struct SecondTag>
int test(int second)
{
return second+7;
}
Second test(Second second)
{
return Second{ second.get()+7 };
}
test(int):
lea eax, [rdi+7]
ret
test(StrongType<int, SecondTag>):
lea eax, [rdi+7]
ret
Output (0/0)
x86-64 gcc 14.2
- 9827ms (84490B) ~6031 lines filtered


C++ now 2024
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CppNow.org
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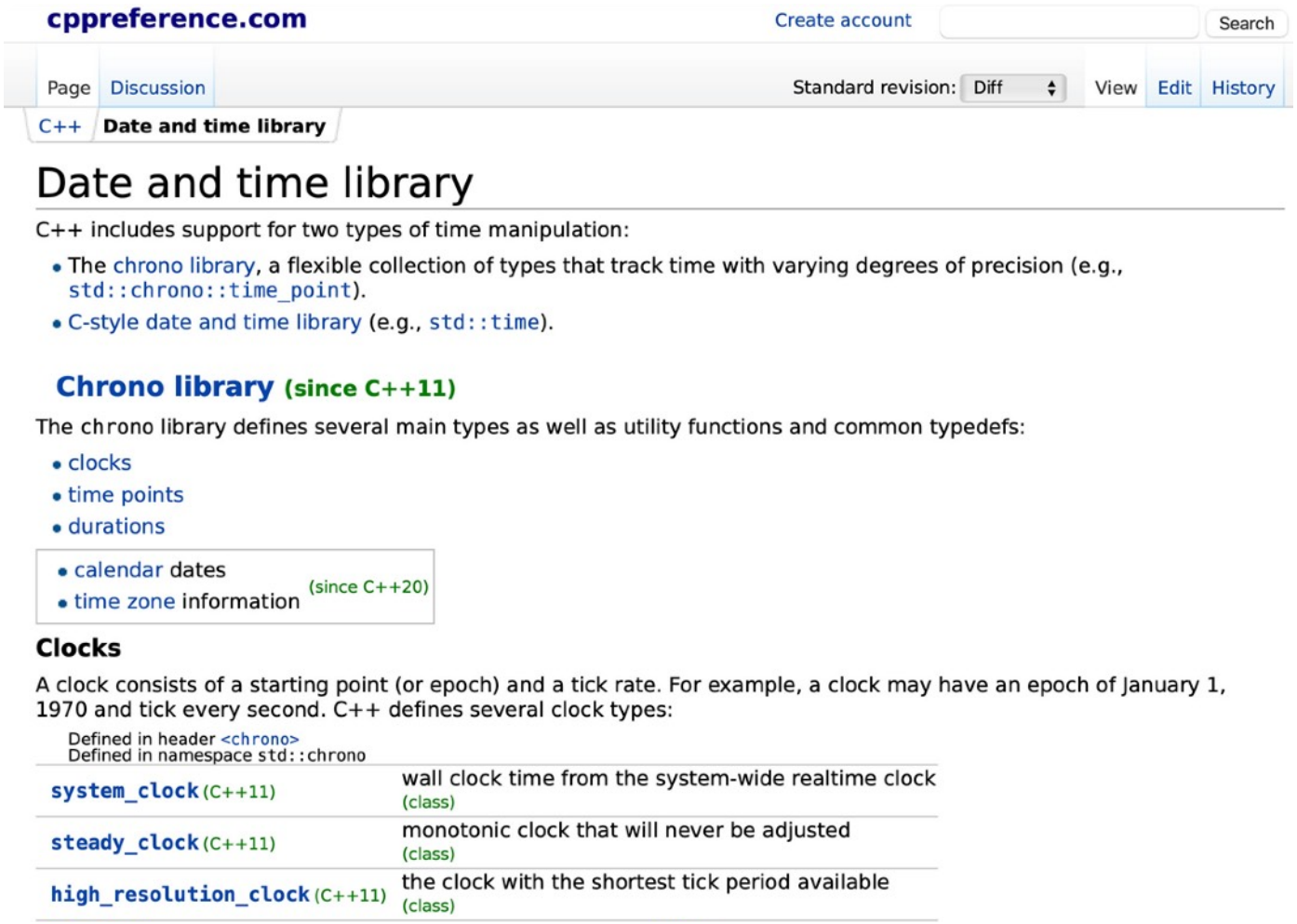
millennium
think-cell
safe
fast
fast
safe
This Is C++
Jon Kalb
10:11 / 1:18:31

Do I have to write all of this myself?

std::chrono Library



cppreference.com Create account Search

Page Discussion Standard revision: Diff View Edit History

C++ Date and time library

Date and time library

C++ includes support for two types of time manipulation:

- The chrono library, a flexible collection of types that track time with varying degrees of precision (e.g., `std::chrono::time_point`).
- C-style date and time library (e.g., `std::time`).

Chrono library (since C++11)

The chrono library defines several main types as well as utility functions and common typedefs:

- clocks
- time points
- durations

- calendar dates
- time zone information (since C++20)

Clocks

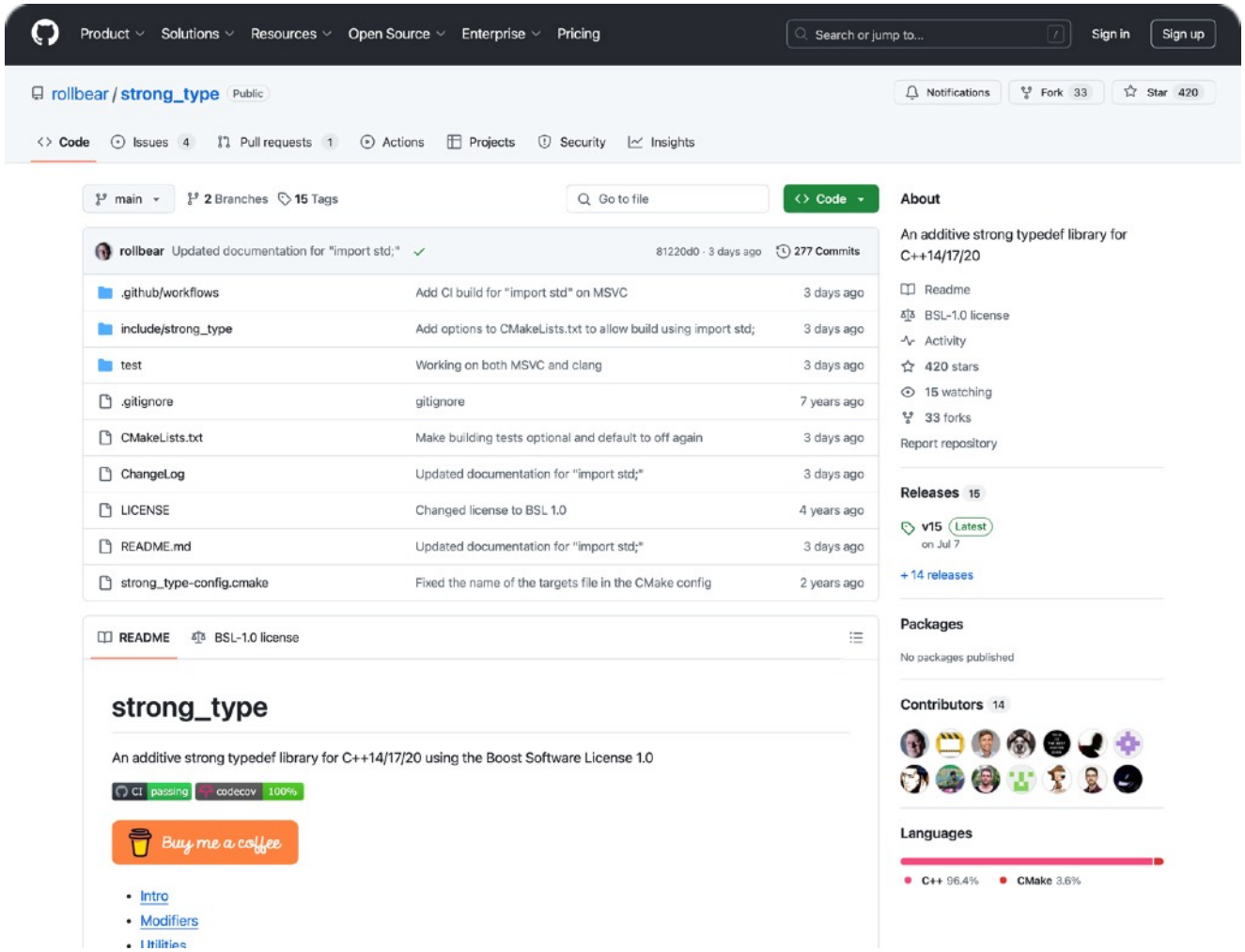
A clock consists of a starting point (or epoch) and a tick rate. For example, a clock may have an epoch of January 1, 1970 and tick every second. C++ defines several clock types:

Defined in header <chrono>
Defined in namespace std::chrono

`system_clock` (C++11)	wall clock time from the system-wide realtime clock (class)
`steady_clock` (C++11)	monotonic clock that will never be adjusted (class)
`high_resolution_clock` (C++11)	the clock with the shortest tick period available (class)

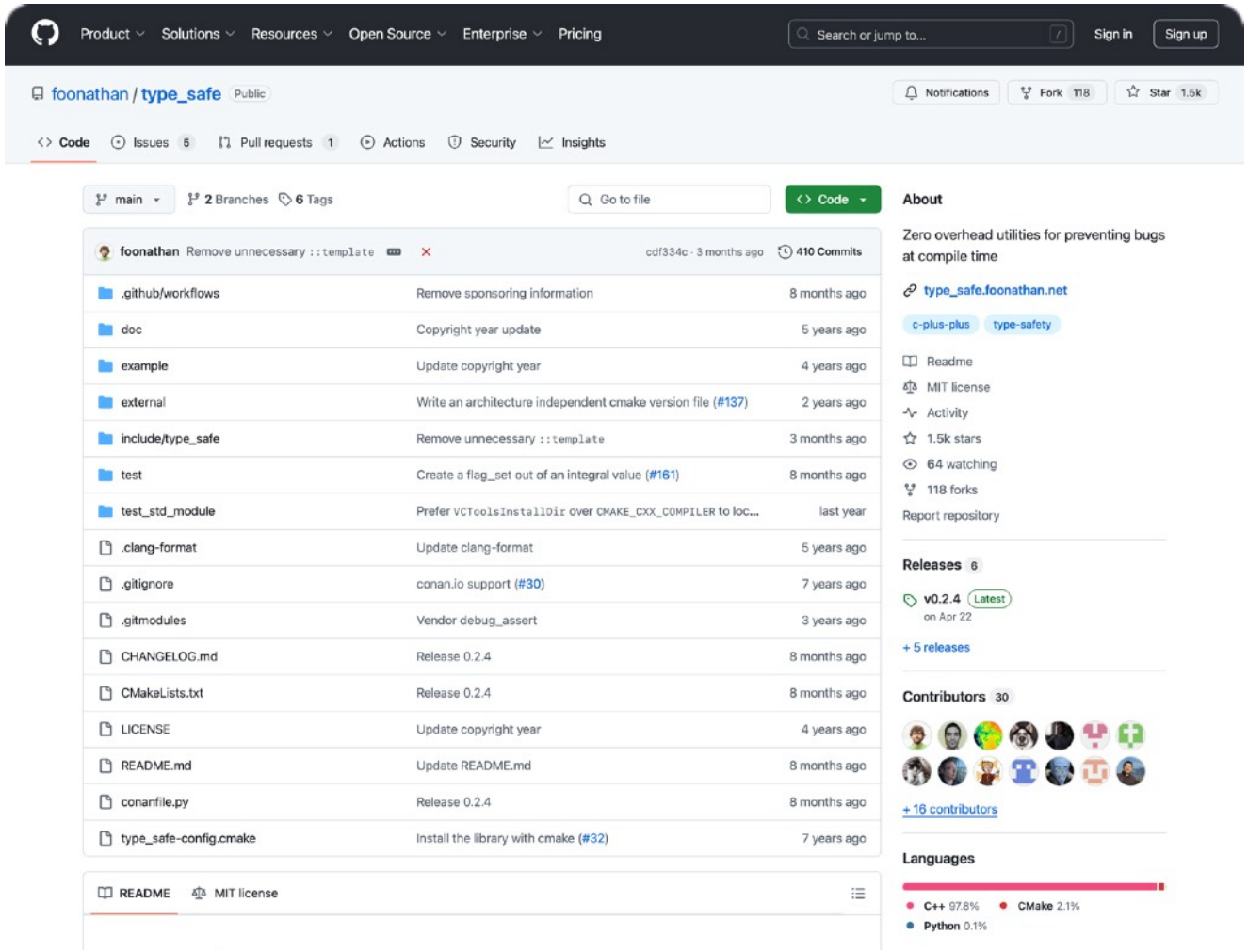
https://en.cppreference.com/w/cpp/chrono

Generic Strong Type Library 1



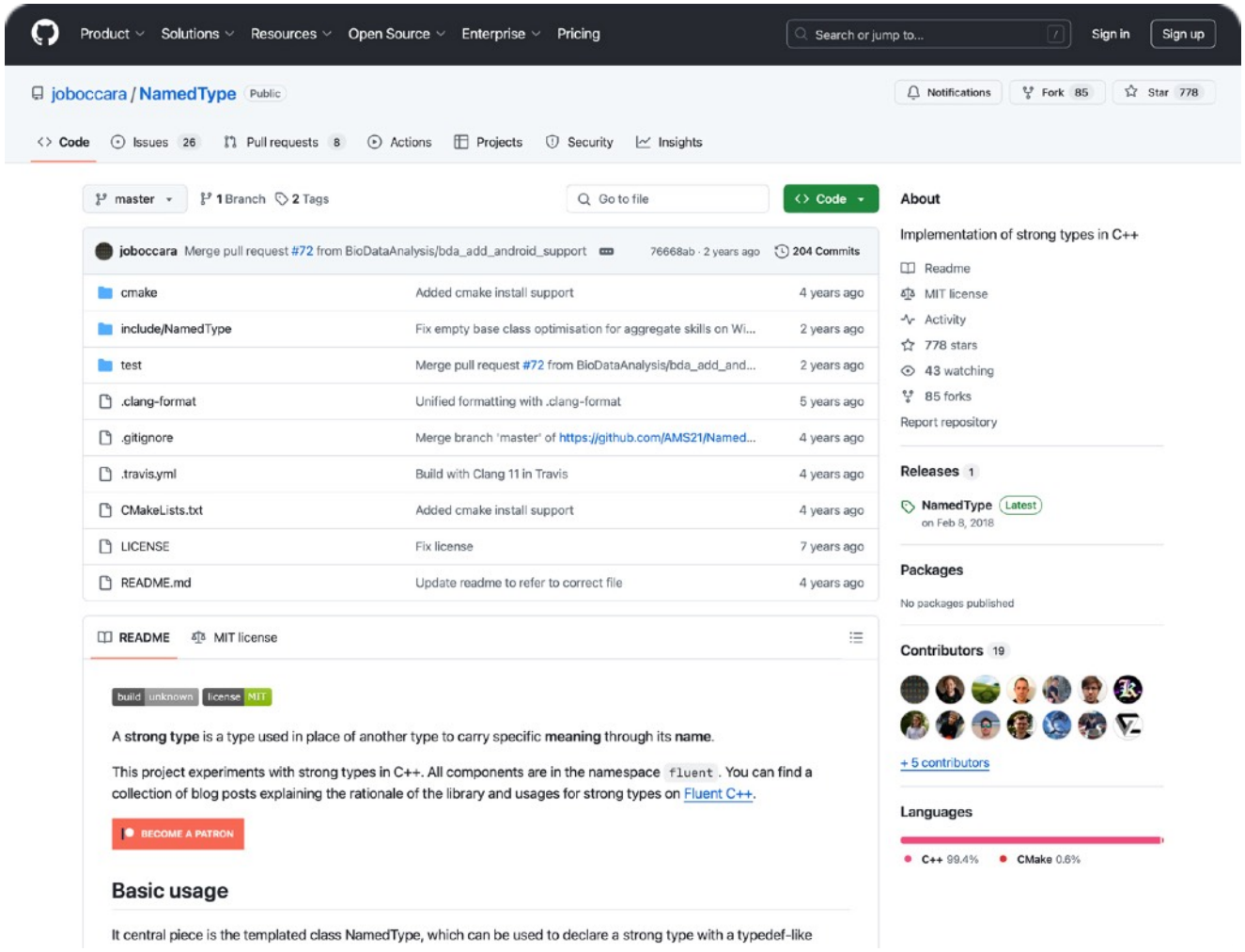
https://github.com/rollbear/strong_type

Generic Strong Type Library 2



https://github.com/foonathan/type_safe

Generic Strong Type Library 3



https://github.com/joboccara/NamedType

Guidelines

Guideline: Prefer strong types to integral and floating point types.

2.5. Initialization Safety

Famine and Fear by theDURRRRIAN

Initialization of Variables

```
int i;
int array[100];
std::string s;
int* pi;

int func()
{
    int i;
    int array[100];
    std::string s;
    int* pi;

    // ...
}

struct Widget
{
    int i;
    int array[100];
    std::string s;
    int* pi;
};
```

Initialization of Static Variables

```
int i;                  // Initialized to 0
int array[100];         // Initialized to all 0s
std::string s;          // Initialized to an empty string
int* pi;                // Initialized to nullptr

int func()
{
    int i;
    int array[100];
    std::string s;
    int* pi;

    // ...
}

struct Widget
{
    int i;
    int array[100];
    std::string s;
    int* pi;
};
```

Initialization of Local Variables

```
int i;                  // Initialized to 0
int array[100];         // Initialized to all 0s
std::string s;          // Initialized to an empty string
int* pi;                // Initialized to nullptr

int func()
{
    int i;              // Uninitialized
    int array[100];     // Uninitialized
    std::string s;      // Initialized to an empty string
    int* pi;            // Uninitialized

    // ...
}

struct Widget
{
    int i;
    int array[100];
    std::string s;
    int* pi;
};
```

Initialization of Member Variables

```
int i;                  // Initialized to 0
int array[100];         // Initialized to all 0s
std::string s;          // Initialized to an empty string
int* pi;                // Initialized to nullptr

int func()
{
   int i;               // Uninitialized
   int array[100];      // Uninitialized
   std::string s;       // Initialized to an empty string
   int* pi;             // Uninitialized

   // ...
}

struct Widget
{
   int i;               // Uninitialised
   int array[100];      // Uninitialized
   std::string s;       // Initialized to an empty string
   int* pi;             // Uninitialized
};
```

Value Initialization

```
int i{};                  // Initialized to 0
int array[100]{};         // Initialized to all 0s
std::string s{};          // Initialized to an empty string
int* pi{};                // Initialized to nullptr

int func()
{
   int i{};               // Initialized to 0
   int array[100]{};      // Initialized to all 0s
   std::string s{};       // Initialized to an empty string
   int* pi{};             // Initialized to nullptr

   // ...
}

struct Widget
{
   int i{};               // Initialized to 0
   int array[100]{};      // Initialized to all 0s
   std::string s{};       // Initialized to an empty string
   int* pi{};             // Initialized to nullptr
};
```

Initialization and Performance

```
int i{};
int array[100]{};
std::string s{};
int* pi{};

int func()
{
    int i{};
    int array[100]{};
    std::string s{};
    int* pi{};

    // ...
}

struct Widget
{
    int i{};
    int array[100]{};
    std::string s{};
    int* pi{};
};
```

Initializing all integers in an array…
Isn’t that too expensive?

Initialization and Performance

```
int i{};
int array[100]{};                    // No; compile-time initialization
std::string s{};
int* pi{};

int func()
{
    int i{};
    int array[100]{};                // Potentially; runtime initialization
    std::string s{};
    int* pi{};

    // ...
}

struct Widget
{
    int i{};
    int array[100]{};                // Potentially; runtime initialization
    std::string s{};
    int* pi{};
};
```

Initialization and Performance

```
int i{};
int array[100]{};                          // Always compile-time initialized
std::string s{};
int* pi{};

int func()
{
   int i{};
   int array[100] // Not initialized;   // Explicitly not initialized
   std::string s{};
   int* pi{};

   // ...
}

struct Widget
{
   int i{};
   int array[100] // Not initialized;   // Explicitly not initialized
   std::string s{};
   int* pi{};
};
```

Initialization and Performance


```cpp
int i{};
int array[100]{};                          // Always compile-time initialized
std::string s{};
int* pi{};

int func()
{
    int i{};
    int array[100] [[indeterminate]];      // C++26: Explicitly not initialized
    std::string s{};
    int* pi{};

    // ...
}

struct Widget
{
    int i{};
    int array[100] [[indeterminate]];      // C++26: Explicitly not initialized
    std::string s{};
    int* pi{};
};
```

Guidelines

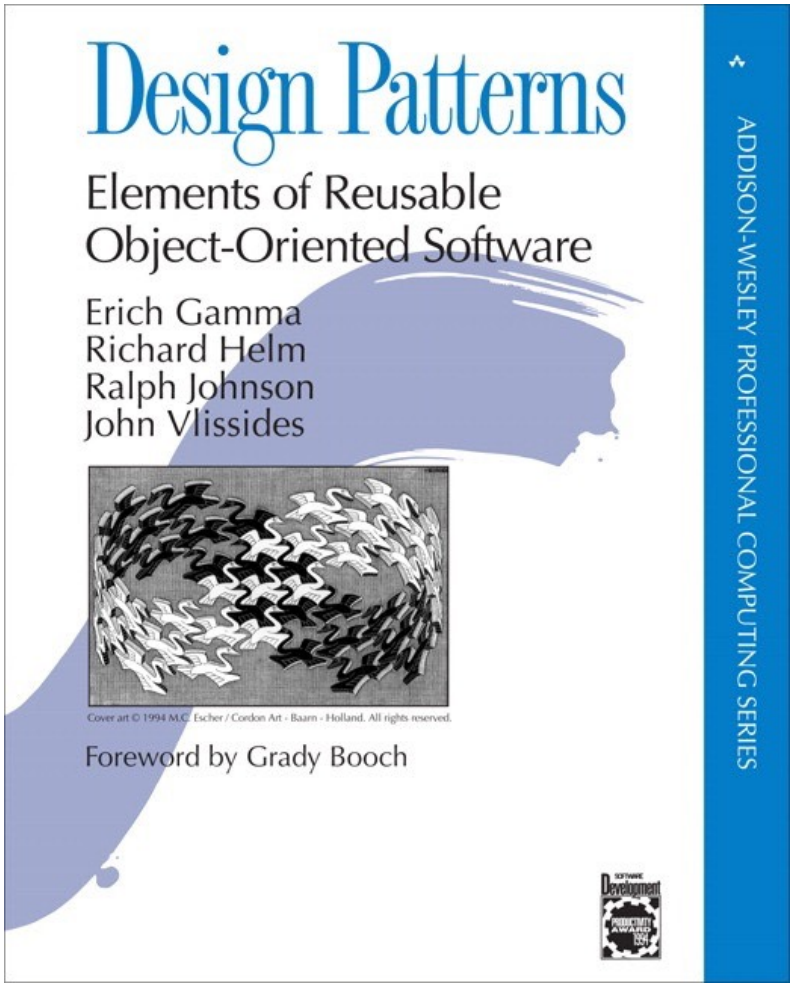
Core Guideline ES.20: Always initialise an object.

Guideline: Prefer to be explicit when not initializing an object, preferably with `[[indeterminate]]`.

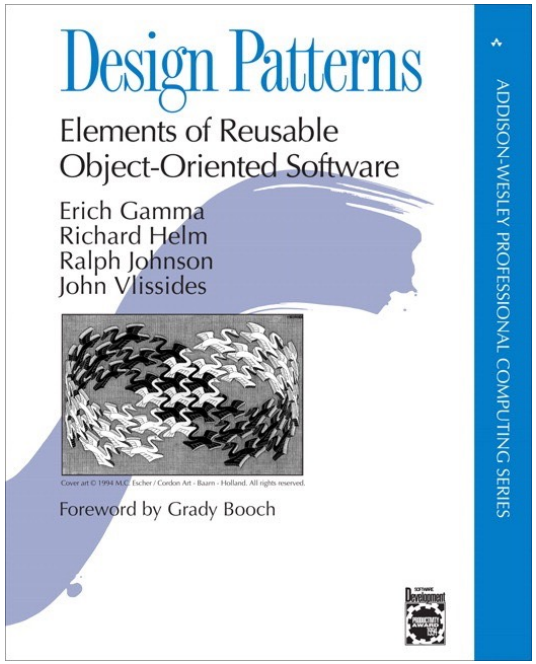
2.6. Lifetime Safety

Death and Despair by theDURRRRIAN

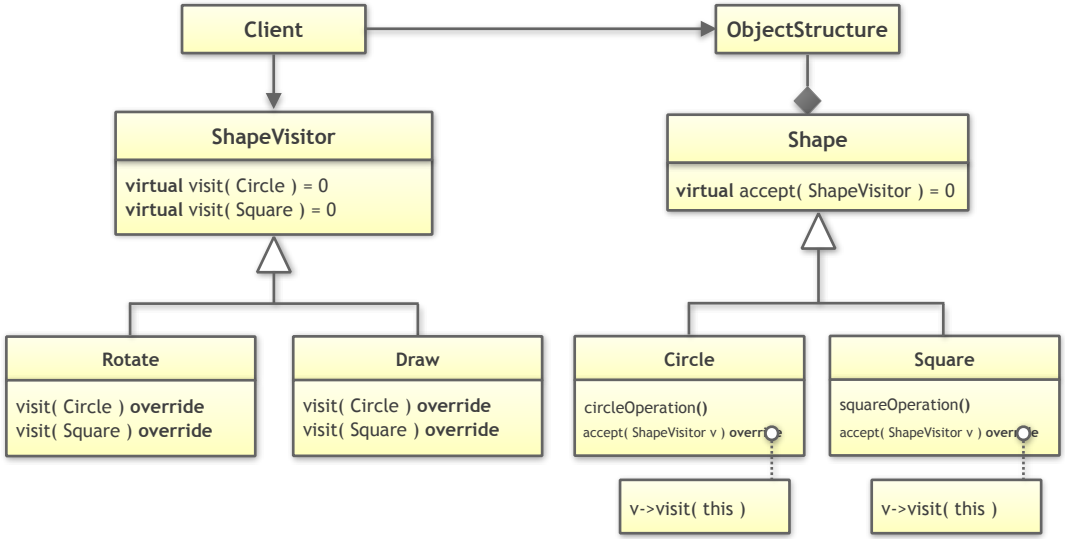
Terminology



- The Gang of Four (GoF) book
- Published in 1994
- Source of 23 of the most commonly used design patterns
- Almost all design patterns are based on inheritance



One of these patterns is the Visitor design pattern



A Visitor-Based Solution

```
class Circle;
class Square;

class ShapeVisitor
{
 public:
   virtual ~ShapeVisitor() = default;

   virtual void visit( Circle const& ) const = 0;
   virtual void visit( Square const& ) const = 0;
};

class Shape
{
 public:
   Shape() = default;
   virtual ~Shape() = default;

   virtual void accept( ShapeVisitor const& ) = 0;
};


class Circle : public Shape
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}
```

A Visitor-Based Solution

```
class Circle;
class Square;

class ShapeVisitor
{
 public:
   virtual ~ShapeVisitor() = default;

   virtual void visit( Circle const& ) const = 0;
   virtual void visit( Square const& ) const = 0;
};

class Shape
{
 public:
   Shape() = default;
   virtual ~Shape() = default;

   virtual void accept( ShapeVisitor const& ) = 0;
};


class Circle : public Shape
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}
```

A Visitor-Based Solution

```
class Circle;
class Square;

class ShapeVisitor
{
 public:
   virtual ~ShapeVisitor() = default;

   virtual void visit( Circle const& ) const = 0;
   virtual void visit( Square const& ) const = 0;
};

class Shape
{
 public:
   Shape() = default;
   virtual ~Shape() = default;

   virtual void accept( ShapeVisitor const& ) = 0;
};


class Circle : public Shape
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}
```

A Visitor-Based Solution

```
   virtual void accept( ShapeVisitor const& ) = 0;
};

class Circle : public Shape
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}

   double getRadius() const noexcept;
   // ... getCenter(), getRotation(), ...

   void accept( ShapeVisitor const& ) override;

   // ...

 private:
   double radius;
   // ... Remaining data members
};

class Square : public Shape
{
 public:
   explicit Square( double s )
      : side{ s }
      , // ... Remaining data members
   {}
```

A Visitor-Based Solution

```
   // ... Remaining data members
};

class Square : public Shape
{
 public:
   explicit Square( double s )
      : side{ s }
      , // ... Remaining data members
   {}

   double getSide() const noexcept;
   // ... getCenter(), getRotation(), ...

   void accept( ShapeVisitor const& ) override;

   // ...

 private:
   double side;
   // ... Remaining data members
};


class Draw : public ShapeVisitor
{
 public:
   void visit( Circle const& ) const override;
   void visit( Square const& ) const override;
};
```

A Visitor-Based Solution

```
    double side;
    // ... Remaining data members
};


class Draw : public ShapeVisitor
{
 public:
    void visit( Circle const& ) const override;
    void visit( Square const& ) const override;
};


void drawAllShapes( std::vector<std::unique_ptr<Shape>> const& shapes )
{
    for( auto const& s : shapes )
    {
        s->accept( Draw{} )
    }
}


int main()
{
    using Shapes = std::vector<std::unique_ptr<Shape>>;

    // Creating some shapes
    Shapes shapes;
    shapes.emplace_back( std::make_unique<Circle>( 2.0 ) );
    shapes.emplace_back( std::make_unique<Square>( 1.5 ) );
```

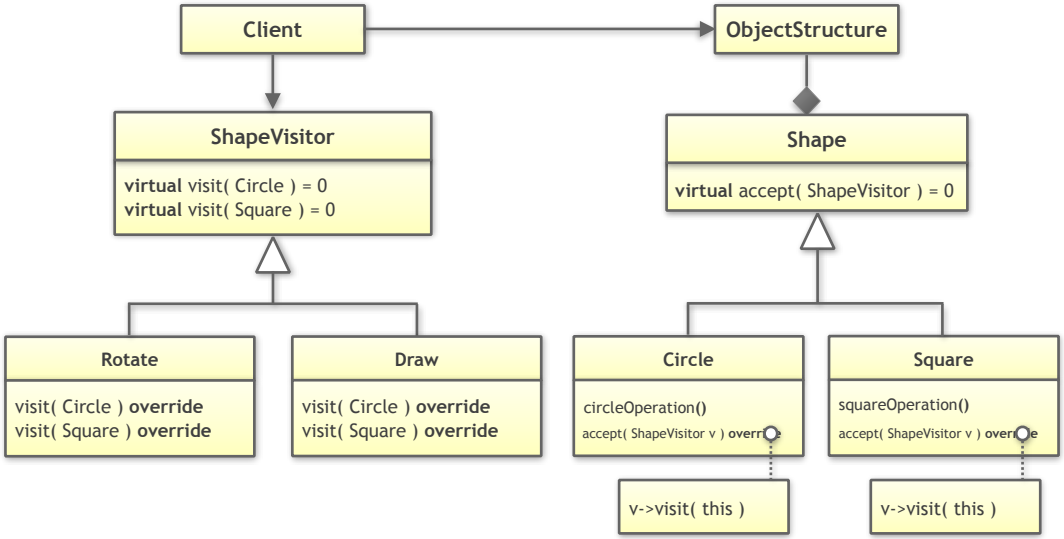
A Visitor-Based Solution

```
void drawAllShapes( std::vector<std::unique_ptr<Shape>> const& shapes )
{
   for( auto const& s : shapes )
   {
      s->accept( Draw{} )
   }
}

int main()
{
   using Shapes = std::vector<std::unique_ptr<Shape>>;

   // Creating some shapes
   Shapes shapes;
   shapes.emplace_back( std::make_unique<Circle>( 2.0 ) );
   shapes.emplace_back( std::make_unique<Square>( 1.5 ) );
   shapes.emplace_back( std::make_unique<Circle>( 4.2 ) );

   // Drawing all shapes
   drawAllShapes( shapes );
}
```



The classic style of programming has many disadvantages:

- We have a **two inheritance hierarchies** (intrusive)
- Performance is reduced due to **two virtual function calls** per operation
- Promotes **dynamic memory allocation**
- Performance is reduced due to **many small, manual allocations**
- We usually **manage lifetimes explicitly** (`std::unique_ptr`)
- Performance is affected due to **many pointers** (indirections)
- Danger of **lifetime-related bugs**

https://www.youtube.com/watch?v=QthAU-t3PQ4

The Solution:

Value Semantics

A Value-Based Solution: std::variant


```
class Circle
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}

   double getRadius() const noexcept;
   // ... getCenter(), getRotation(), ...

 private:
   double radius;
   // ... Remaining data members
};


class Square
{
 public:
   explicit Square( double s )
      : side{ s }
      , // ... Remaining data members
   {}

   double getSide() const noexcept;
   // ... getCenter(), getRotation(), ...

 private:
   double side;
```

A Value-Based Solution: std::variant


```
class Circle
{
 public:
   explicit Circle( double rad )
      : radius{ rad }
      , // ... Remaining data members
   {}

   double getRadius() const noexcept;
   // ... getCenter(), getRotation(), ...

 private:
   double radius;
   // ... Remaining data members
};


class Square
{
 public:
   explicit Square( double s )
      : side{ s }
      , // ... Remaining data members
   {}

   double getSide() const noexcept;
   // ... getCenter(), getRotation(), ...

 private:
   double side;
```

A Value-Based Solution: std::variant


```
 private:
   double radius;
   // ... Remaining data members
};


class Square
{
 public:
   explicit Square( double s )
      : side{ s }
      , // ... Remaining data members
   {}

   double getSide() const noexcept;
   // ... getCenter(), getRotation(), ...

 private:
   double side;
   // ... Remaining data members
};


using Shape = std::variant<Circle,Square>;


class GLDrawer
{
 public:
   void operator()( Circle const& ) const;
   void operator()( Square const& ) const;
```

A Value-Based Solution: std::variant


```
 private:
   double side;
   // ... Remaining data members
};

using Shape = std::variant<Circle,Square>;

class GLDrawer
{
 public:
   void operator()( Circle const& ) const;
   void operator()( Square const& ) const;
   // ...
};

void drawAllShapes( std::vector<Shape> const& shapes )
{
   for( auto const& s : shapes )
   {
      std::visit( GLDrawer{}, s );
   }
}

int main()
{
   using Shapes = std::vector<Shape>;
```

A Value-Based Solution: std::variant


```
 private:
   double side;
   // ... Remaining data members
};

using Shape = std::variant<Circle,Square>;

class GLDrawer
{
 public:
   void operator()( Circle const& ) const;
   void operator()( Square const& ) const;
   // ...
};

void drawAllShapes( std::vector<Shape> const& shapes )
{
   for( auto const& s : shapes )
   {
      std::visit( GLDrawer{}, s );
   }
}

int main()
{
   using Shapes = std::vector<Shape>;
```

A Value-Based Solution: std::variant


```
 private:
   double side;
   // ... Remaining data members
};

using Shape = std::variant<Circle,Square>;

class GLDrawer
{
 public:
   void operator()( Circle const& ) const;
   void operator()( Square const& ) const;
   // ...
};

void drawAllShapes( std::vector<Shape> const& shapes )
{
   for( auto const& s : shapes )
   {
      std::visit( GLDrawer{}, s );
   }
}

int main()
{
   using Shapes = std::vector<Shape>;
```

A Value-Based Solution: std::variant


```
void drawAllShapes( std::vector<Shape> const& shapes )
{
   for( auto const& s : shapes )
   {
      std::visit( GLDrawer{}, s );
   }
}

int main()
{
   using Shapes = std::vector<Shape>;

   // Creating some shapes
   Shapes shapes;
   shapes.emplace_back( Circle{ 2.0 } );
   shapes.emplace_back( Square{ 1.5 } );
   shapes.emplace_back( Circle{ 4.2 } );

   // Drawing all shapes
   drawAllShapes( shapes );
}
```

From Pointers/References to Values

Task (2_Safe_Cpp/Visitor_Refactoring):

Step 1: Implement the `area()` operations as a classic visitor. Hint: the area of a circle is `radius*radius*M_PI`, the area of a square is `side*side`.

Step 2: Refactor the classic Visitor solution by a value semantics based solution. Note that the general behavior should remain unchanged.

Step 3: Switch from one to another graphics library. Discuss the feasibility of the change: how easy is the change? How many pieces of code on which level of the architecture have to be touched?

Step 4: Add the new feature to serialize shapes by means of the `FastSerialization` library. Observe how well the new code can be integrated and how many new dependencies are created.

Step 5: Discuss the advantages of the value semantics based solution in comparison to the classic solution.

From Pointers/References to Values

Task (2_Safe_Cpp/Strategy_Refactoring):

Step 1: Refactor the classic Strategy solution by a value semantics based solution. Note that the general behavior should remain unchanged.

Step 2: Switch from one to another graphics library. Discuss the feasibility of the change: how easy is the change? How many pieces of code on which level of the architecture have to be touched?

Step 3: Add an `area()` operations for all shapes. How easy is the change? How many pieces of code on which level of the architecture have to be touched? Hint: the area of a circle is `radius*radius*M_PI`, the area of a square is `side*side`.

Step 4: Add the new feature to serialize shapes by means of the `FastSerialization` library. Observe how well the new code can be integrated and how many new dependencies are created.

https://www.youtube.com/watch?v=PEcy1vYHb8A

https://www.youtube.com/watch?v=4eeESJQk-mw

From Pointers/References to Values

Task (2_Safe_Cpp/ToInt): Compare the five different solutions to convert a string into an integer and think about the pros and cons of every solution.

From Pointers/References to Values


```cpp
#include <charconv>
#include <optional>
#include <string_view>

std::optional<int> to_int( std::string_view sv )
{
   std::optional<int> oi{};
   int i{};

   auto const result =
      std::from_chars( sv.data(), sv.data() + sv.size(), i );

   if( result.ec != std::errc::invalid_argument ) {
      oi = i;
   }

   return oi;
}
```

Guidelines

Guideline: Prefer value semantics to reference semantics.

Guideline: Try to reduce the use of pointers.

2.7. The Sharp Edges

But sometimes I have to write dangerous code: low-level details, memory management, pointer arithmetic, … How do I deal with these situations?

Yes, once in a while you'll have to deal with such details. Best practice is to do encapsulate those details as best as possible.

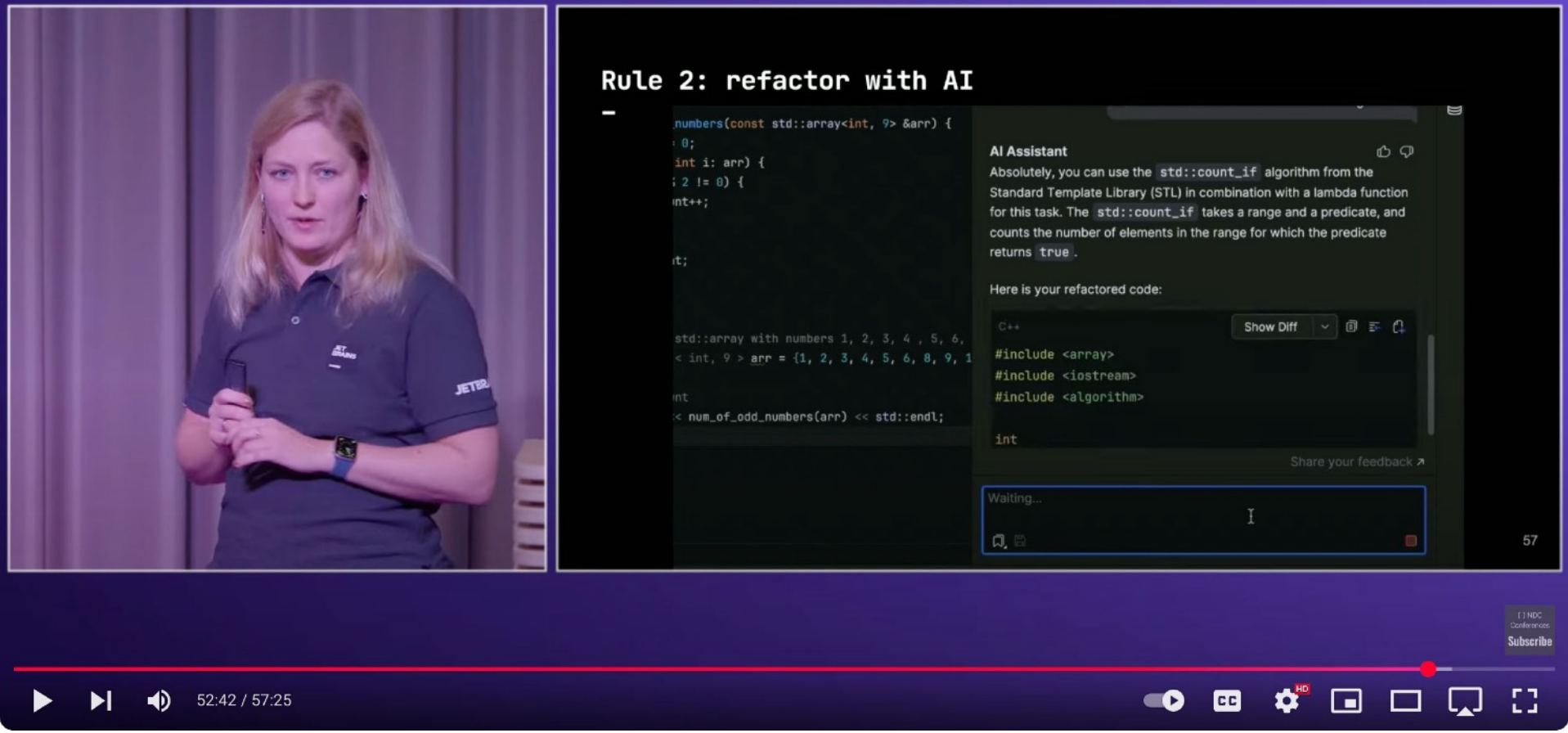
Encapsulate the dangerous/tricky parts

- **Encapsulate** everything dangerous/tricky into separate entities
- This is what other programming languages force you to do
- Write **specific tests** for these parts
- Do **more reviews** or even **code inspections**
- Use **pair programming** for these parts
- And perhaps above all else: **use the available tools**
  - IDEs
  - Static code analysis
  - Sanitizers
  - Fuzzers
  - …

IDEs

- CLion (JetBrains)
- MS Visual Studio (Microsoft)
- …

Keynote: How To Address 7 Major C++ Pain Points with Tools - Anastasiia Kazakova - NDC TechTown 2024



https://www.youtube.com/watch?v=U3I3eaRKDBk

Static Code Analysis

- Clang-Tidy (LLVM)
- CppCheck (Daniel Marjamaki)
- …

Extra Clang Tools 21.0.0git documentation

CLANG-TIDY

Clang-Tidy

Contents

See also:

- List of Clang-Tidy Checks
- Clang-tidy IDE/Editor Integrations
- Getting Involved
- External Clang-Tidy Examples

clang-tidy is a clang-based C++ "linter" tool. Its purpose is to provide an extensible framework for diagnosing and fixing typical programming errors, like style violations, interface misuse, or bugs that can be deduced via static analysis. **clang-tidy** is modular and provides a convenient interface for writing new checks.

Using Clang-Tidy

clang-tidy is a LibTooling-based tool, and it's easier to work with if you set up a compile command database for your project (for an example of how to do this, see How To Setup Tooling For LLVM). You can also specify compilation options on the command line after `--`:

```
$ clang-tidy test.cpp -- -Imy_project/include -DMY_DEFINES ...
```

If there are too many options or source files to specify on the command line, you can store them in a parameter file, and use **clang-tidy** with that parameters file:

```
$ clang-tidy @parameters_file
```

clang-tidy has its own checks and can also run Clang Static Analyzer checks. Each check has a name and the checks to run can be chosen using the `-checks=` option, which specifies a comma-separated list of positive and negative (prefixed with `-`) globs. Positive globs add subsets of checks, and negative globs remove

See also:

- List of Clang-Tidy Checks
- Clang-tidy IDE/Editor Integrations
- Getting Involved
- External Clang-Tidy Examples

clang-tidy is a clang-based C++ "linter" tool. Its purpose is to provide an extensible framework for diagnosing and fixing typical programming errors, like style violations, interface misuse, or bugs that can be deduced via static analysis. **clang-tidy** is modular and provides a convenient interface for writing new checks.

Using Clang-Tidy

clang-tidy is a LibTooling-based tool, and it's easier to work with if you set up a compile command database for your project (for an example of how to do this, see How To Setup Tooling For LLVM). You can also specify compilation options on the command line after `--`:

```
$ clang-tidy test.cpp -- -Imy_project/include -DMY_DEFINES ...
```

If there are too many options or source files to specify on the command line, you can store them in a parameter file, and use **clang-tidy** with that parameters file:

```
$ clang-tidy @parameters_file
```

clang-tidy has its own checks and can also run Clang Static Analyzer checks. Each check has a name and the checks to run can be chosen using the `-checks=` option, which specifies a comma-separated list of positive and negative (prefixed with `-`) globs. Positive globs add subsets of checks, and negative globs remove them. For example,

```
$ clang-tidy test.cpp -checks=-*,clang-analyzer-*,-clang-analyzer-cplusplus*
```

Cppcheck

A tool for static C/C++ code analysis

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Cppcheck is a static analysis tool for C/C++ code. It provides unique code analysis to detect bugs and focuses on detecting undefined behaviour and dangerous coding constructs. The goal is to have very few false positives. Cppcheck is designed to be able to analyze your C/C++ code even if it has non-standard syntax (common in embedded projects).

Cppcheck is available both as open-source (this page) and as **Cppcheck Premium** with extended functionality and support. Please visit www.cppcheck.com for more information and purchase options for the commercial version.

Download

Cppcheck 2.17 (open source)

Platform	File
Windows 64-bit (No XP support)	Installer
Source code (.zip)	Archive
Source code (.tar.gz)	Archive

Packages

Cppcheck can also be installed from various package managers; however, you might get an outdated version then.

Packages

Cppcheck can also be installed from various package managers; however, you might get an outdated version then.

Debian:

```
sudo apt-get install cppcheck
```

Fedora:

```
sudo yum install cppcheck
```

Mac:

```
brew install cppcheck
```

Features

Unique code analysis that detect various kinds of bugs in your code.

Both command line interface and graphical user interface are available.

Cppcheck has a strong focus on detecting undefined behaviour.

Unique analysis

Unique analysis

Using several static analysis tools can be a good idea. There are unique features in each tool. This has been established in many studies.

So what is unique in Cppcheck.

Cppcheck uses unsound flow sensitive analysis. Several other analyzers use path sensitive analysis based on abstract interpretation, that is also great however that has both advantages and disadvantages. In theory by definition, it is better with path sensitive analysis than flow sensitive analysis. But in practice, it means Cppcheck will detect bugs that the other tools do not detect.

In Cppcheck the data flow analysis is not only "forward" but "bi-directional". Most analyzers will diagnose this:

```
void foo(int x)
{
    int buf[10];
    if (x == 1000)
        buf[x] = 0; // <- ERROR
}
```

Most tools can determine that the array index will be 1000 and there will be overflow.

Cppcheck will also diagnose this:

```
void foo(int x)
{
    int buf[10];
    buf[x] = 0; // <- ERROR
    if (x == 1000) {}
}
```

Cppcheck will also diagnose this:

```
void foo(int x)
{
    int buf[10];
    buf[x] = 0; // <- ERROR
    if (x == 1000) {}
}
```

Undefined behaviour

- Dead pointers
- Division by zero
- Integer overflows
- Invalid bit shift operands
- Invalid conversions
- Invalid usage of STL
- Memory management
- Null pointer dereferences
- Out of bounds checking
- Uninitialized variables
- Writing const data

Security

The most common types of security vulnerabilities in 2017 (CVE count) was:

Category	Amount	Detected by Cppcheck
Buffer Errors	2530	A few
Improper Access Control	1366	A few (unintended backdoors)
Information Leak	1426	A few (unintended backdoors)
Permissions, Privileges, and Access Control	1196	A few (unintended backdoors)

Programming Task

Task (2_Safe_Cpp/CppCheck): Use CppCheck to detect the following bugs in the example program: division-by-0, use of uninitialized variables, out-of-bounds access, and use-after-free..

Sanitizers

- Part of every modern C++ compiler
- Address Sanitizer (ASan)
  - Use after free/return/scope
  - Heap/Stack/Global buffer overflow
  - Initialization order bugs
  - Memory leaks
- Memory Sanitizer (MSan)
  - detection of uninitialised memory reads
- Thread Sanitizer (TSan)
  - data race detected
- Undefined Behavior Sanitizer (UBSan)
- …

Programming Task

Task (3_Concepts_and_STL/constexpr/AddressSanitizer): Use AddressSanitizer to detect the out-of-bounds access in the following demo code.

google / sanitizers

Type / to search

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AddressSanitizer

chefmax edited this page on May 15, 2019 · 29 revisions

Introduction

AddressSanitizer (aka ASan) is a memory error detector for C/C++. It finds:

- Use after free (dangling pointer dereference)
- Heap buffer overflow
- Stack buffer overflow
- Global buffer overflow
- Use after return
- Use after scope
- Initialization order bugs
- Memory leaks

This tool is very fast. The average slowdown of the instrumented program is ~2x (see AddressSanitizerPerformanceNumbers).

The tool consists of a compiler instrumentation module (currently, an LLVM pass) and a run-time library which replaces the `malloc` function.

The tool works on x86, ARM, MIPS (both 32- and 64-bit versions of all architectures), PowerPC64. The supported operation systems are Linux, Darwin (OS X and iOS Simulator), FreeBSD, Android:

OS	x86	x86_64	ARM	ARM64	MIPS	MIPS64	PowerPC	PowerPC64
Linux	yes	yes			yes	yes	yes	yes
OS X	yes	yes						
iOS Simulator	yes	yes						

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    - gdb
    - ulimit -v
  - Flags
  - Call stack
  - Incompatibility
  - Turning off instrumentation
  - FAQ
  - Talks and papers
  - Comments?
- AddressSanitizerAlgorithm
- AddressSanitizerAndDebugger
- AddressSanitizerAndroidPlatform
- AddressSanitizerAsDso

Adress Sanitizer

```
            countries.insert( pos, country );
        }
    }

    std::vector<Country> five_biggest_countries{ begin(countries), begin(countries)+5U };

    for( size_t i=1U; i<5U; ++i )
    {
        auto& country1 = five_biggest_countries[i-1U];
        for( size_t j=i; j<5U; ++j ) {
            auto& country2 = five_biggest_countries[j];
            if( country1.residents < country2.residents ) {
                Country tmp{ country1 };
                country1 = country2;
                country2 = tmp;
            }
        }
    }

    for( auto const& country : five_biggest_countries ) {
        std::cout << country << '\n';
    }
}
```

Let's assume that there are only 4 countries instead of a minimum of 5

Address Sanitizer

```
=================================================================
==88511==ERROR: AddressSanitizer: heap-buffer-overflow on address 0x611000000150 at pc 0x0001082bfe14 bp
READ of size 8 at 0x611000000150 thread T0
    #0 0x0001082bfe13 in __asan_memcpy+0xf23 (libclang_rt.asan_osx_dynamic.dylib:x86_64h+0xd7e13)
    #1 0x0001078dea58 in Country::Country(Country const&)+0x58 (AddressSanitizer:x86_64+0x100011a58)
    #2 0x0001078cfd3c in Country::Country(Country const&)+0x1c (AddressSanitizer:x86_64+0x100002d3c)
    #3 0x0001078d7798 in Country* std::__1::construct_at[abi:ne190106]<Country, Country&, Country*>(Count
    #4 0x0001078d775c in Country* std::__1::__construct_at[abi:ne190106]<Country, Country&, Country*>(Cou
    #5 0x0001078d7730 in _ZNSt3__116allocator_traitsINS_9allocatorI7CountryEEE9constructB8ne190106IS2_JRS
    #6 0x0001078d722d in Country* std::__1::__uninitialized_allocator_copy_impl[abi:ne190106]<std::__1::a
    #7 0x0001078de475 in Country* std::__1::__uninitialized_allocator_copy[abi:ne190106]<std::__1::alloca
(AddressSanitizer:x86_64+0x100011475)
    #8 0x0001078de29f in void std::__1::vector<Country, std::__1::allocator<Country>>::__construct_at_end
    #9 0x0001078dde02 in void std::__1::vector<Country, std::__1::allocator<Country>>::__init_with_size[a
    #10 0x0001078ddb93 in _ZNSt3__16vectorI7CountryNS_9allocatorIS1_EEEC2INS_11__wrap_iterIPS1_EETnNS_9en
    #11 0x0001078cfcc4 in _ZNSt3__16vectorI7CountryNS_9allocatorIS1_EEEC1INS_11__wrap_iterIPS1_EETnNS_9en
    #12 0x0001078ce9bd in print_countries()+0xe9d (AddressSanitizer:x86_64+0x1000019bd)
    #13 0x0001078d03d3 in main+0x13 (AddressSanitizer:x86_64+0x1000033d3)
    #14 0x7ff8123ec344 in start+0x774 (dyld:x86_64+0xffffffffff5c344)

0x611000000150 is located 48 bytes after 224-byte region [0x611000000040,0x611000000120)
allocated by thread T0 here:
    #0 0x0001082d6a6d in _Znwm+0x7d (libclang_rt.asan_osx_dynamic.dylib:x86_64h+0xeea6d)
    #1 0x0001078d1ae4 in void* std::__1::__libcpp_operator_new[abi:ne190106]<unsigned long>(unsigned long
    #2 0x0001078d1a62 in std::__1::__libcpp_allocate[abi:ne190106](unsigned long, unsigned long)+0x42 (Ad
    #3 0x0001078d19d5 in std::__1::allocator<Country>::allocate[abi:ne190106](unsigned long)+0x45 (Addres
    #4 0x0001078d14cc in std::__1::__allocation_result<std::__1::allocator_traits<std::__1::allocator<Cou
    #5 0x0001078dbe7b in std::__1::__split_buffer<Country, std::__1::allocator<Country>&>::__split_buffer
    #6 0x0001078d982c in std::__1::__split_buffer<Country, std::__1::allocator<Country>&>::__split_buffer
    #7 0x0001078cf857 in std::__1::vector<Country, std::__1::allocator<Country>>::insert(std::__1::__wrap
    #8 0x0001078ce8db in print_countries()+0xdbb (AddressSanitizer:x86_64+0x1000018db)
```

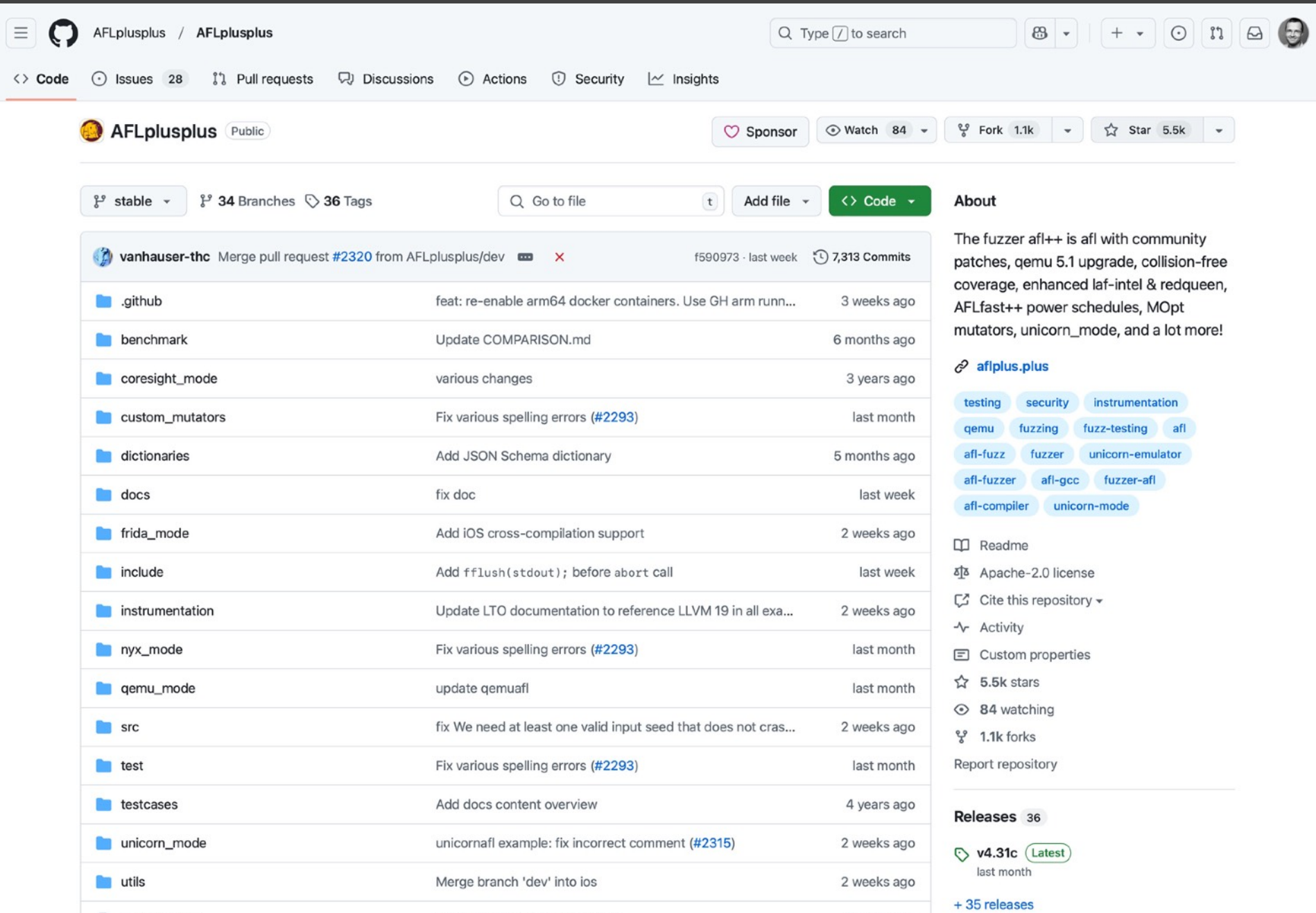
Address Sanitizer

```
SUMMARY: AddressSanitizer: heap-buffer-overflow (AddressSanitizer:x86_64+0x100011a58) in Country::Country
Shadow bytes around the buggy address:
  0x610ffffffe80: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x610fffffff00: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x610fffffff80: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
  0x611000000000: fa fa fa fa fa fa fa fa 00 00 00 00 00 00 00 00
  0x611000000080: 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00 00
=>0x611000000100: 00 00 00 00 fa fa fa fa fa fa[fa]fa fa fa fa fa
  0x611000000180: fd fd fd fd fd fd fd fd fd fd fd fd fd fd fd fd
  0x611000000200: fd fd fd fd fd fd fd fd fd fd fd fd fd fd fd fa
  0x611000000280: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x611000000300: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
  0x611000000380: fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa fa
Shadow byte legend (one shadow byte represents 8 application bytes):
  Addressable:           00
  Partially addressable: 01 02 03 04 05 06 07
  Heap left redzone:       fa
  Freed heap region:       fd
  Stack left redzone:      f1
  Stack mid redzone:       f2
  Stack right redzone:     f3
  Stack after return:      f5
  Stack use after scope:   f8
  Global redzone:          f9
  Global init order:       f6
  Poisoned by user:        f7
  Container overflow:      fc
  Array cookie:            ac
  Intra object redzone:    bb
  ASan internal:           fe
  Left alloca redzone:     ca
  Right alloca redzone:    cb
```

Fuzzers

- AFL++
- Google/fuzztest
- …

2. Safe C++ – The Sharp Edges



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vanhauser-thc Merge pull request #2320 from AFLplusplus/dev f590973 · last week 7,313 Commits

.github	feat: re-enable arm64 docker containers. Use GH arm runn...	3 weeks ago
benchmark	Update COMPARISON.md	6 months ago
coresight_mode	various changes	3 years ago
custom_mutators	Fix various spelling errors (#2293)	last month
dictionaries	Add JSON Schema dictionary	5 months ago
docs	fix doc	last week
frida_mode	Add iOS cross-compilation support	2 weeks ago
include	Add `fflush(stdout);` before `abort` call	last week
instrumentation	Update LTO documentation to reference LLVM 19 in all exa...	2 weeks ago
nyx_mode	Fix various spelling errors (#2293)	last month
qemu_mode	update qemuafl	last month
src	fix We need at least one valid input seed that does not cras...	2 weeks ago
test	Fix various spelling errors (#2293)	last month
testcases	Add docs content overview	4 years ago
unicorn_mode	unicornafl example: fix incorrect comment (#2315)	2 weeks ago
utils	Merge branch 'dev' into ios	2 weeks ago

About

The fuzzer afl++ is afl with community patches, qemu 5.1 upgrade, collision-free coverage, enhanced laf-intel & redqueen, AFLfast++ power schedules, MOpt mutators, unicorn_mode, and a lot more!

aflplus.plus

testing security instrumentation qemu fuzzing fuzz-testing afl afl-fuzz fuzzer unicorn-emulator afl-fuzzer afl-gcc fuzzer-afl afl-compiler unicorn-mode

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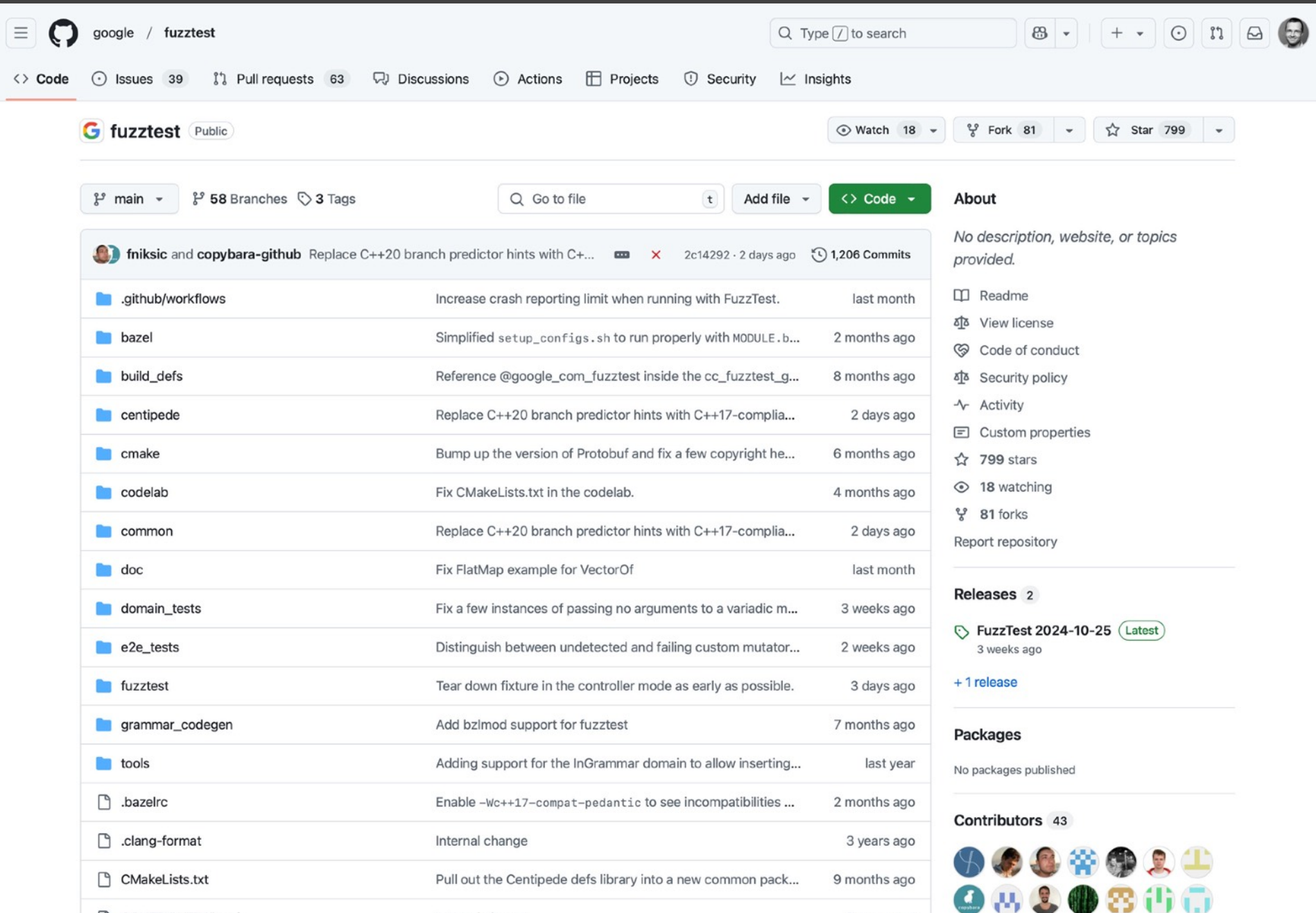
2. Safe C++ – The Sharp Edges



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fniksic and copybara-github Replace C++20 branch predictor hints with C+... 2c14292 · 2 days ago 1,206 Commits

.github/workflows	Increase crash reporting limit when running with FuzzTest.	last month
bazel	Simplified `setup_configs.sh` to run properly with `MODULE.b...`	2 months ago
build_defs	Reference @google_com_fuzztest inside the cc_fuzztest_g...	8 months ago
centipede	Replace C++20 branch predictor hints with C++17-complia...	2 days ago
cmake	Bump up the version of Protobuf and fix a few copyright he...	6 months ago
codelab	Fix CMakeLists.txt in the codelab.	4 months ago
common	Replace C++20 branch predictor hints with C++17-complia...	2 days ago
doc	Fix FlatMap example for VectorOf	last month
domain_tests	Fix a few instances of passing no arguments to a variadic m...	3 weeks ago
e2e_tests	Distinguish between undetected and failing custom mutator...	2 weeks ago
fuzztest	Tear down fixture in the controller mode as early as possible.	3 days ago
grammar_codegen	Add bzlmod support for fuzztest	7 months ago
tools	Adding support for the InGrammar domain to allow inserting...	last year
.bazelrc	Enable `-Wc++17-compat-pedantic` to see incompatibilities ...	2 months ago
.clang-format	Internal change	3 years ago
CMakeLists.txt	Pull out the Centipede defs library into a new common pack...	9 months ago

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No packages published

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Guidelines

Guideline: Use the available tools to help to detect problems.

Guideline: It is considered unprofessional today to not use static code analysis, sanitizers, a test framework and fuzzers.

2.8. Summary

What can we do?

I can do my part as C++ trainer/consultant

But we also need YOU!

Spread the word that working in classic C++ is like grovelling in the dirt

Tell people to stand up, to become proud C++ developers that know about the best practices and use the tools

"With our best practices and tools we can easily remove the vast majority of safety issues."

(Klaus Iglberger)

”If there were 90-98% fewer C++ type/bounds/initialization/lifetime vulnerabilities we wouldn’t be having this discussion.”

(Herb Sutter)

Summary

- Programming in C++ isn't safe by default, we have do some homework
- We have great solutions to eliminate most common safety problems
  - Most bounds safety issues (> 95%) can be resolved by not using indices/ iterators (algorithms, ranges, …)
  - 100% type safety by strong types and constraints (C++20 concepts)
  - Almost all lifetime safety issues (~ 99%) can be resolved by using value semantics
  - No undefinded behavior by constexpr and sanitisers
- These are not new solutions, by now they are mainstream — use them!
- Use the idiomatic rules and tools of C++
  - You cannot complain about safety issues if you don't use these tools
- It's a people problem: Too few people use the idiomatic C++ of today
- Help to spread the information how C++ should be used today

References (Safety)

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References (Strong Types)

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- Jonathan Müller: Tutorial: Emulating strong/opaque typedefs in C++. foonathan::blog() (https://foonathan.net/2016/10/strong-typedefs/)
- Alex Dathskovsky: To Int or to Uint, This is the Question. CppCon 2024 (https://www.youtube.com/watch?v=pnaZ0x9Mmm0)

References (Tools)

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- MS Visual Studio Code: https://code.visualstudio.com/
- Clang Tidy: https://clang.llvm.org/extra/clang-tidy/
- CppCheck: https://cppcheck.sourceforge.io/
- AddressSanitizer: https://github.com/google/sanitizers/wiki/AddressSanitizer
- AFL++: https://aflplus.plus/
- Google/fuzztest: https://github.com/google/fuzztest

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Xing: xing.com/profile/Klaus_Iglberger/cv