Quantifying Accidental Complexity

An empirical look at teaching and using C++

Herb Sutter

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Why complexity matters

We're "paying taxes" all the time

- Productivity
- Correctness and quality
- Tooling
- Teaching, learning, hiring, training

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Common claim:
"C++ is too complex"

This talk's contribution:
Empirically catalog, classify, and count

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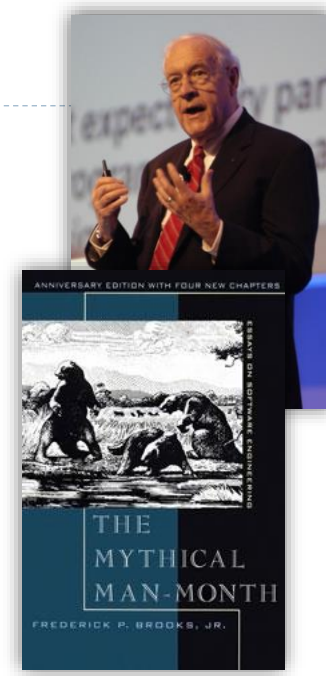
Fred Brooks: Complexity

Essential complexity

Inherent in the problem, present in any solution

Accidental complexity PUSH

Artifact of a specific solution design



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Some of C++'s rich "guidance" corpus

Catalogued so far (638 rules)

Google: Abseil Tips

Meyers: Effective C++ Third Edition

Meyers: Effective Modern C++

Meyers: More Effective C++

Meyers: "Breaking All the Eggs in C++"

Perforce: High Integrity C++ 4.0

Sutter & Alexandrescu: C++ Coding Standards

(in progress) PVS-Studio

Pending

CERT: CERT standard checks

Clang: clang-tidy checks

Lockheed-Martin & Stroustrup: Joint Strike Fighter Air Vehicle coding std. for C++, Rev C

(upcoming) MISRA: MISRA C++ 202x

Stroustrup & Sutter, eds.: C++ Core Guidelines

Sutter: Exceptional C++

Sutter: More Exceptional C++

Sutter: Exceptional C++ Style

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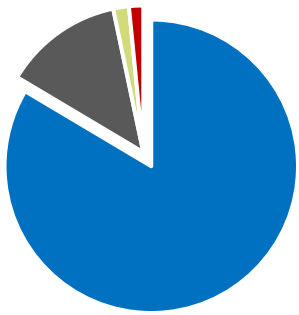
Breakdown of first 638 rules catalogued

533 language

84 std:: library

11 general/local

10 wrong (IMO)



Even "wrong" was informative…

It often it arose because the language was complex / offered multiple ways to do a thing

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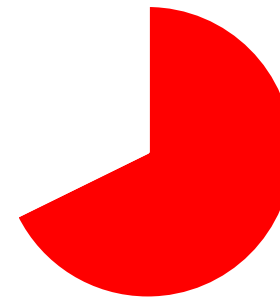
Breakdown of first 638 rules catalogued

533 language

361 accidental + improvable



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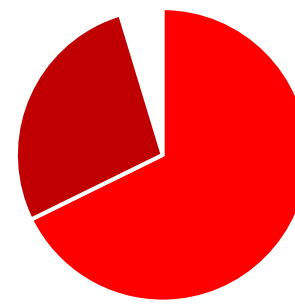
Breakdown of first 638 rules catalogued

533 language

147 'essential' + improvable

361 accidental + improvable



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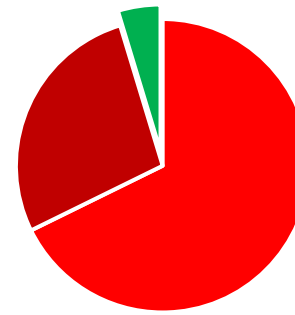
Breakdown of first 638 rules catalogued

533 language

25 essential + minimal
147 'essential' + improvable
361 accidental + improvable



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Is there a "10× silver bullet"?

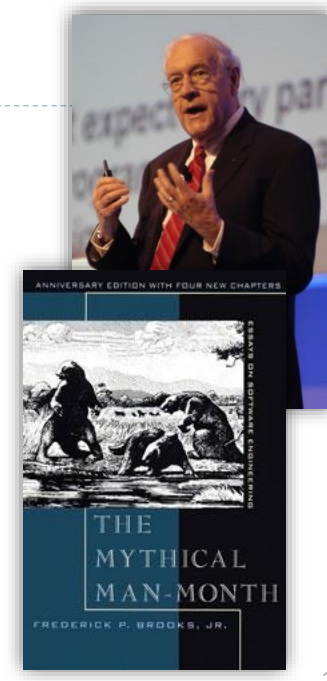
Brooks famously concluded: **"No silver bullet"**

> Conclusion: "There is no single development, in either technology or management technique, **which by itself promises even one order-of-magnitude improvement** within a decade in productivity, in reliability, in simplicity."

But, note Brooks' premise:

> Premise: "How much of what software engineers now do is still devoted to the accidental, as opposed to the essential? **Unless it is more than 9/10 of all effort, shrinking the accidental activities to zero time will not give an order of magnitude improvement.**"
>
> Therefore: We have a large problem **and a large opportunity**.

"No Silver Bullet," 1986; in *The Mythical Man-Month* Anniversary Ed.



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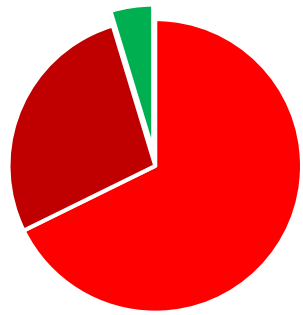
Is there a "10× silver bullet"?



"**Unless it is more than 9/10 of all effort, shrinking the accidental activities to zero time will not give an order of magnitude improvement.**"

Therefore: We have a large problem **and a large opportunity**.

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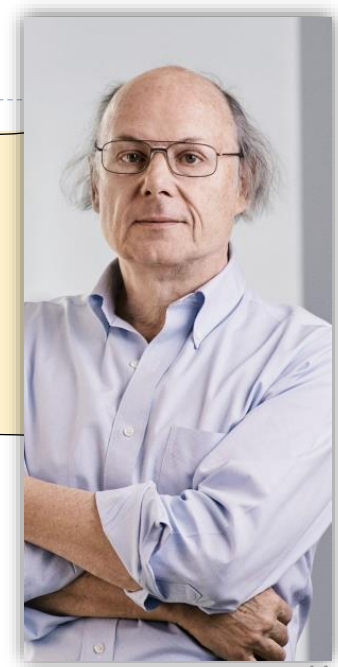
Bjarne Stroustrup on "10×"

"**Inside C++, there is a much smaller and cleaner language** struggling to get out."
— B. Stroustrup (D&E, 1994)

"**Say 10% of the size of C++**... Most of the simplification would come from **generalization**."
— B. Stroustrup (ACM HOPL-III, 2007)



"**Unless it is more than 9/10 of all effort, shrinking the accidental activities to zero time will not give an order of magnitude improvement.**"

Therefore: We have a large problem **and a large opportunity**.

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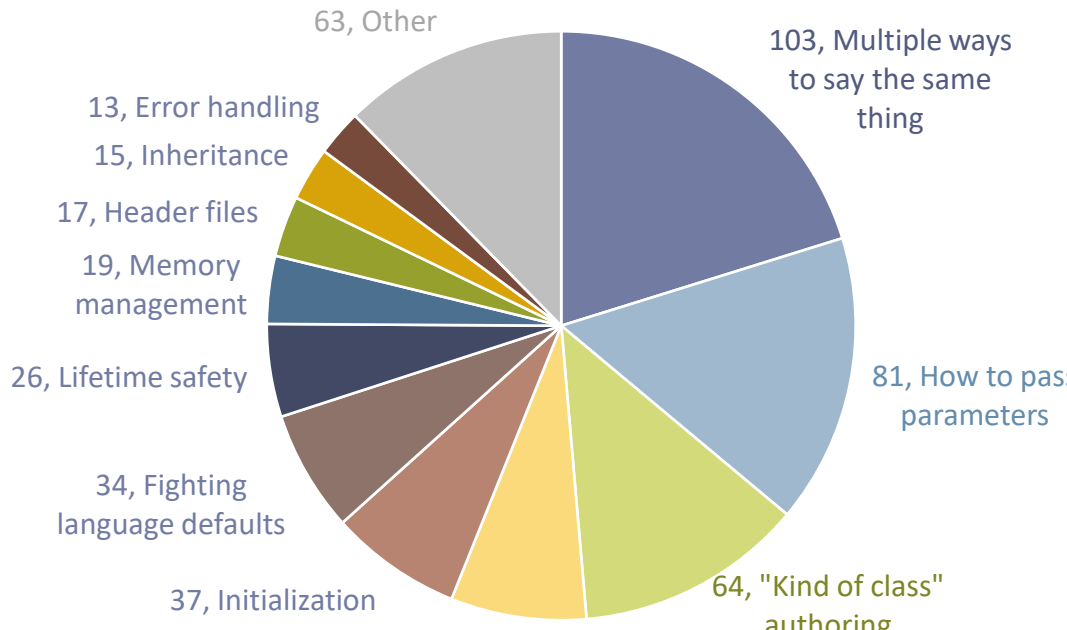

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Common claim:
"C++ is too complex"

This talk's contribution:
Empirically catalog, classify, and count

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Common claim:
"C++ is too complex"

This talk's contribution:
Empirically catalog, classify, and count

Common despair:
"We can't make things substantially better"

This talk's contribution:
A possible 30% reduction
... 1/3 of the way to 10×

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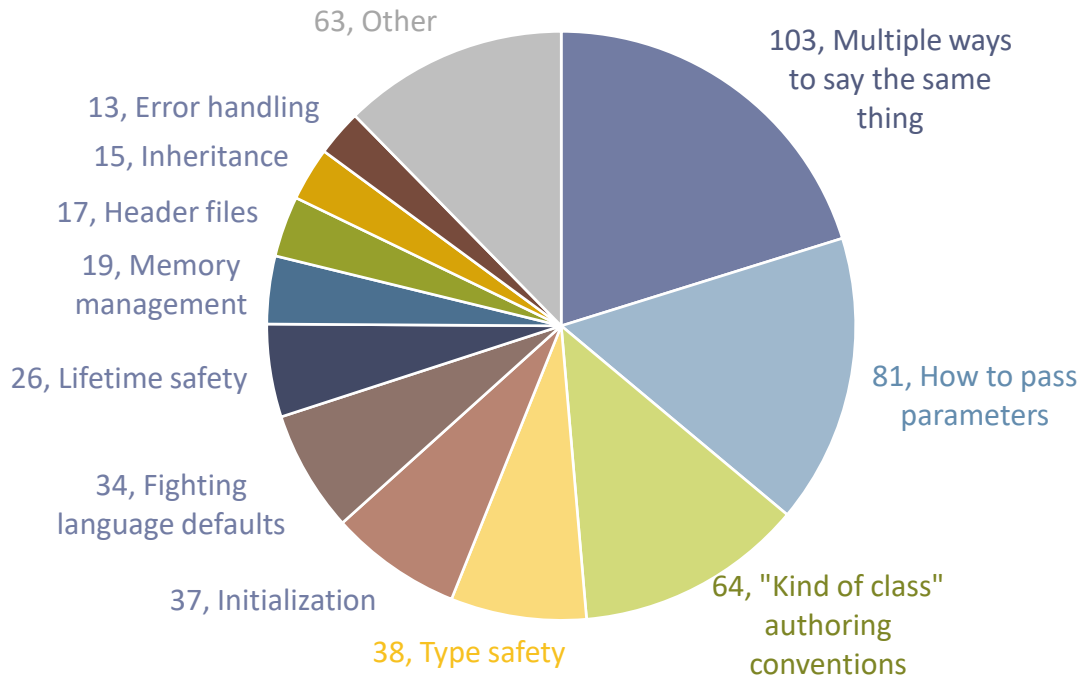

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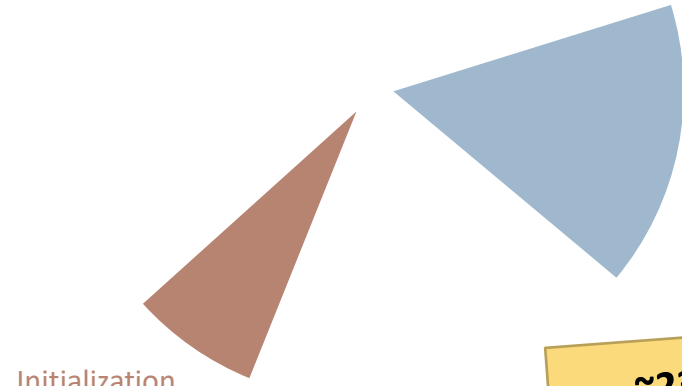

~23% of this body of popular C++ guidance is about how to **pass parameters** and **initialize objects**

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Today we teach: **"How"** to pass by value/&/&&

	What we teach today: "How" mechanics
In	Pass by value for "cheap to copy/move" types (incl. builtin types) Otherwise, pass by **const X&** + **Overload** non-templated rvalue reference **X&&** + **std::move** once to optimize rvalues **except** if X must be a type parameter, write templated forwarding reference **X&&** + **enable_if/requires is_reference_v<X>** and **std::forward** instead **except** consider passing **X by value** if it's an "**in+copy**" parameter to a constructor
In-out	Pass by non-const **X&**
Out	Pass by non-const **X&** + nonstd annotations Can't distinguish from in-out in the language Can't enforce write-before-read or must-write
Move	Pass by non-templated rvalue reference **X&&** + **std::move** once **except** if X must be a type parameter, write templated forwarding reference **X&&** + **enable_if/requires !is_reference_v<X>** and **std::forward** instead
Forward	Pass by templated forwarding reference **T&&** + **std::forward** once **and** if we want only a concrete type X, add **enable_if/requires is_convertible_v<T,X>**

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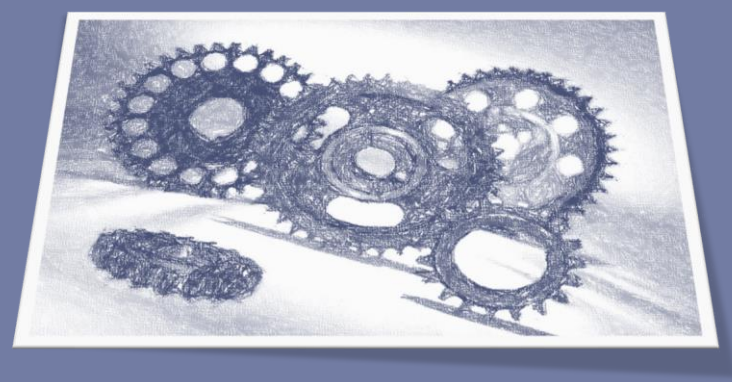
Aim to enable "what," not "how"



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Upgrade: Declare **"what"** instead

Declare intent directly:

```
f (       in X x  )     // an X I can read from
f (    inout X x  )     // an X I can read and write
f (      out X x  )     // an X I will assign to
f (     move X x  )     // an X I will move from
f ( forward X x  )     // an X I will pass along
```

That's it… all I'd like to teach about passing parameters in C++.

Most of the following slides are for people who already had to learn **today's complex thing**, to explain how it maps to the simpler thing.

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"Definite first/last use" (see also P1179, Ada, C#)

```
void sample(... x, ... y) {
    process(x);
    if (something(x)) {
        process(y);
        x.hold();
    } else {
        cout << x;
    }
    transfer(y);
}
```

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"Definite first/last use" (see also P1179, Ada, C#)

```
void sample(... x, ... y) {
    process(x);              // definite first use of x
    if (something(x)) {
        process(y);
        x.hold();
    } else {
        cout << x;
    }
    transfer(y);
}
```

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24

"Definite first/last use" (see also P1179, Ada, C#)

```
void sample(... x, ... y) {
    process(x);              // definite first use of x
    if (something(x)) {
        process(y);
        x.hold();            // definite last use of x
    } else {
        cout << x;           // definite last use of x
    }
    transfer(y);
}
```

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25

"Definite first/last use" (see also P1179, Ada, C#)

```
void sample(... x, ... y) {
    process(x);              // definite first use of x
    if (something(x)) {
        process(y);
        x.hold();            // definite last use of x
    } else {
        cout << x;           // definite last use of x
    }
    transfer(y);             // definite last use of y
}
```

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	in X x
Calling convention	X if cheap to copy, else X*
Caller arguments	Initialized object (l- or rvalue)
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)

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50kft overview: "in"

C++20

```
void f1(int x) {
    g(x);
}
```

```
void f2(const X& x) { // for lvalues
    g(x);
}
void f2(X&& x) {      // for rvalues
    g(std::move(x));
}   // remember to move only once
```

```
template<typename T>
void f3(const T& t) {
    g(t);
}
// hard to overload to pass by value
// hard to overload for rvalues
```

Proposed equivale

```
void f1(in int x) {
    g(x);
}
```

```
void f2(in X x) {
    g(x);
}
```

```
template<typename T>
void f3(in T t) {
    g(t);
}
```

efficient: copies builtins and moves from rvalues (even if f2 is a template)

simple and safe: can't modify param, implicitly move for last copy if rvalue

simple and clear: no need to overload to optimize values, call std::move, or remember to pass builtins by value

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	in X x	inout X x
Calling convention	X if cheap to copy, else X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)

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50kft overview: "inout"

C++20

```
void f1(/*inout*/ X& x) {
    g(x);       // ok
    x = 42;     // ok but can omit
}

void f2(/*inout*/ X& x) {
    y = x * 2;  // ok
} // not flagged: did not write to x

// can't distinguish inout vs out
```

Proposed equivalent

```
void f1(inout X x) {
    g(x);
    x = 42;     // ok and required
}

void f2(inout X x) {
    y = x * 2;
} // error, did not write to x
```

simple and safe: read-before-write from x is okay, but failure to write to x is not okay

simple and clear: can distinguish between inout and out

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	in X x	inout X x	out X x
Calling convention	X if cheap to copy, else X*	X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue	Any non-const lvalue
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)	Every path must have a definite first use, that either assigns to x or passes x to another out param

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50kft overview: "out"

C++20

```
void f1(/*out*/ X& x) {
    g(x);       // not flagged: read
    x = 42;     // ok but can omit
    g(x);       // ok
}
```

```
void f2(/*out*/ X& x) {
    /* ... no write to x ... */
} // not flagged: did not write to x
```

```
// can't distinguish inout vs out
```

Proposed equivalent

```
void f1(out X x) {
    g(x);       // error
    x = 42;     // ok, required
    g(x);       // ok
}
```

```
void f2(out X x) {
    /* ... no write to x ... */
} // error, did not write to x
```

simple and safe: error to read-before-write or fail to write; use-after-write is ok

simple and clear: can distinguish between inout and out; out *is* value return where the caller allocates the storage

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	in X x	inout X x	out X x	move X x
Calling convention	X if cheap to copy, else X*	X*	X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue	Any non-const lvalue	Initialized non-const rvalue
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)	Every path must have a definite first use, that either assigns to x or passes x to another out param	x is treated as a non-const lvalue Except each definite last use of x treats it as an rvalue and must be to a move parameter

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50kft overview: "move"

C++20

```
void f1(X&& x) {
    g(std::move(x));
}
```

```
template<typename T>
    requires (!std::is_reference_v<T>)
void f2(T&& t) {   // not an rref...
    container.emplace_back
        (std::forward<T>(t));
} // ... so "forward" instead of move
```

moving generic types is cumbersome

Proposed equivalent

```
void f1(move X x) {
    g(x);
}
```

```
template<typename T>
void f2(move T t) {
    container.emplace_back(t);
}
```

simple and clear: allows consuming a parameter even in a template

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	in X x	inout X x	out X x	move X x	forward X x
Calling convention	X if cheap to copy, else X*	X*	X*	X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue	Any non-const lvalue	Initialized non-const rvalue	Any object (l- or rvalue)
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)	Every path must have a definite first use, that either assigns to x or passes x to another out param	x is treated as a non-const lvalue Except each definite last use of x treats it as an rvalue and must be to a move parameter	x is treated as a const lvalue Except each definite last use preserves the arg's const-ness and l/r-valueness

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50kft overview: "forward"

C++20

```
template<typename T>
void f1(T&& t) {
    container.emplace_back
        (std::forward<T>(t));
}
```

```
template<typename T> // must be template
  requires is_convertible_v<T, X>
   // or: is_same_v<remove_cvref_t<T>,X>
void f2(T&& x) {
    g(std::forward<T>(x));
}
```

forwarding concrete types is difficult

Proposed equivalent

```
template<typename T>
void f1(forward T t) {
    container.emplace_back(t);
}
```

```
void f2(forward X x) {
    g(x);
}
```

simple and clear: allows forwarding a parameter without a template or std::forward

supports generic and concrete types: allows forwarding generic and concrete types

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Demos

Clang-based prototype available at

cppx.godbolt.org

Prototype implemented by **Andrew Sutton** (Lock3 Software)

and hosted with thanks by **Matt Godbolt** (Aquatic)

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Demo's little helpers

```
//  copy_from: take any number of arguments by value/copy
void copy_from(auto...) { }

//  run_history: Run some code and return the history it generated
std::string history;
auto run_history(auto f) {  history = {};  f();  return history;  }

//  noisy<T>: A little helper to conveniently instrument T's SMF history
template<typename T> struct noisy {
    T t;
    noisy()                                 { history += "default-ctor "; }
    ~noisy()                                { history += "dtor "; }
    noisy(const noisy& rhs) : t{rhs.t}      { history += "copy-ctor "; }
    noisy(noisy&& rhs) : t{std::move(rhs.t)} { history += "move-ctor "; }
    auto operator=(const noisy& rhs)        { history += "copy-assign ";
                                              t = rhs.t; return *this; }
    auto operator=(noisy&& rhs)             { history += "move-assign ";
                                              t = std::move(rhs.t); return *this; }
};
```

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demo-in-1

***Simple** guidance,*
***non**-template,*
***one** parameter*

cppx.godbolt.org/z/xEx15c

```
//-----------------------------------------------
//  Today's "old" in-parameter implementation -
//-----------------------------------------------

void old_in(int i) {
    copy_from(i);
}


//-----------------------------------------------
//  Proposed "new" in-parameter implementation
//-----------------------------------------------

void new_in(in int i) {
    copy_from(i);
}
```

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demo-in-2

***Simple** guidance,*
***non**-template,*
***one** parameter*

cppx.godbolt.org/z/fGTbc6

```
//-----------------------------------------------
//  Today's "old" in-parameter implementation -
//-----------------------------------------------

void old_in(const String& s) {
    copy_from(s);
}

void old_in(String&& s) {
    copy_from(std::move(s));
}


//-----------------------------------------------
//  Proposed "new" in-parameter implementation
//-----------------------------------------------

void new_in(in String s) {
    copy_from(s);
}
```

40

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demo-in-3

***Simple** guidance,*
***non**-template,*
***two** parameters*

cppx.godbolt.org/z/ne1dv1

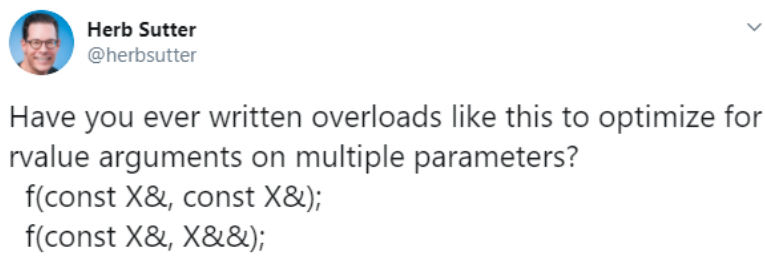
```
//----------------------------------------------------------------------
//  Today's "old" in-parameter implementation - two parameters
//----------------------------------------------------------------------

void old_in(const String& s1, const String& s2) {
    copy_from(s1);
    copy_from(s2);
}

void old_in(String&& s1, const String& s2) {
    copy_from(std::move(s1));
    copy_from(s2);
}

void old_in(const String& s1, String&& s2) {
    copy_from(s1);
    copy_from(std::move(s2));
}

void old_in(String&& s1, String&& s2) {
    copy_from(std::move(s1));
    copy_from(std::move(s2));
}


//----------------------------------------------------------------------
//  Proposed "new" in-parameter implementation - simple - two parameters
//----------------------------------------------------------------------

void new_in(in String s1, in String s2) {
    copy_from(s1);
    copy_from(s2);
}
```

250

120

41

41



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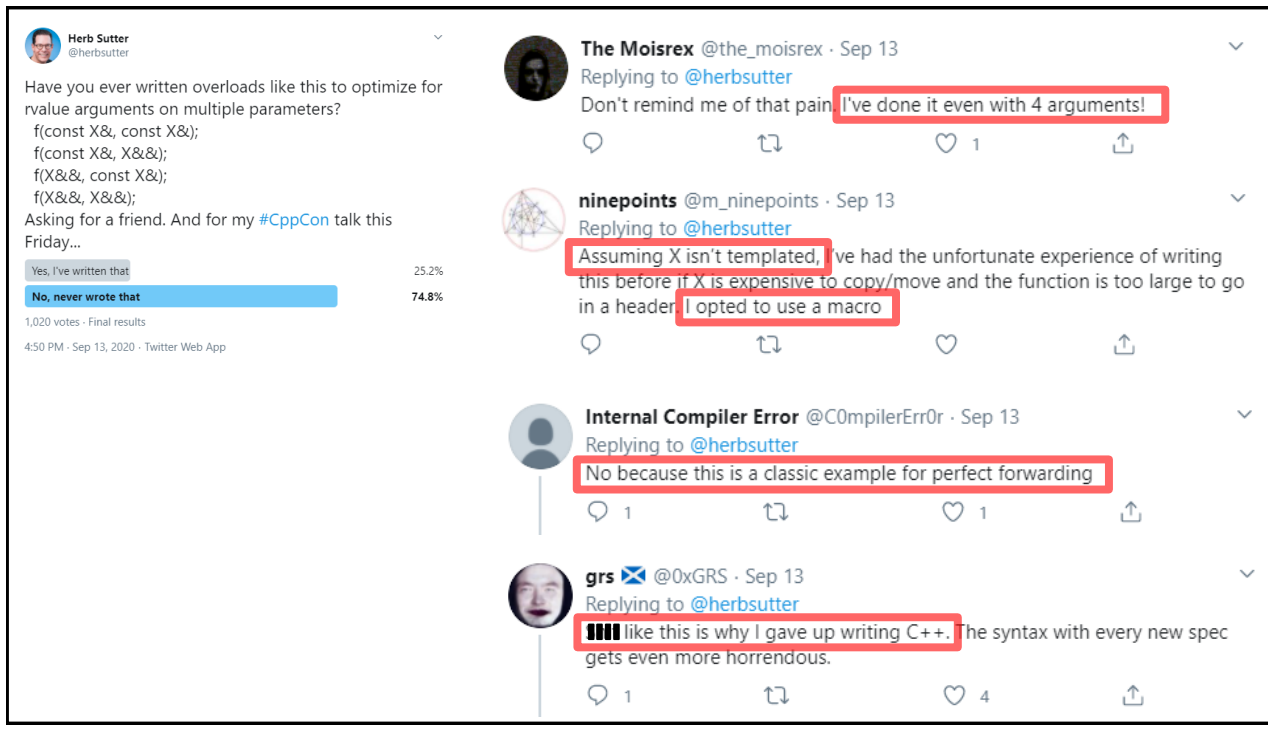
Herb Sutter
@herbsutter
Have you ever written overloads like this to optimize for rvalue arguments on multiple parameters?
f(const X&, const X&);
f(const X&, X&&);
f(X&&, const X&);
f(X&&, X&&);
Asking for a friend. And for my #CppCon talk this Friday...
Yes, I've written that
25.2%
No, never wrote that
74.8%
1,020 votes · Final results
4:50 PM · Sep 13, 2020 · Twitter Web App
The Moisrex @the_moisrex · Sep 13
Replying to @herbsutter
Don't remind me of that pain. I've done it even with 4 arguments!
ninepoints @m_ninepoints · Sep 13
Replying to @herbsutter
Assuming X isn't templated, I've had the unfortunate experience of writing this before if X is expensive to copy/move and the function is too large to go in a header. I opted to use a macro
Internal Compiler Error @C0mpilerErr0r · Sep 13
Replying to @herbsutter
No because this is a classic example for perfect forwarding
grs @0xGRS · Sep 13
Replying to @herbsutter
[redacted] like this is why I gave up writing C++. The syntax with every new spec gets even more horrendous.

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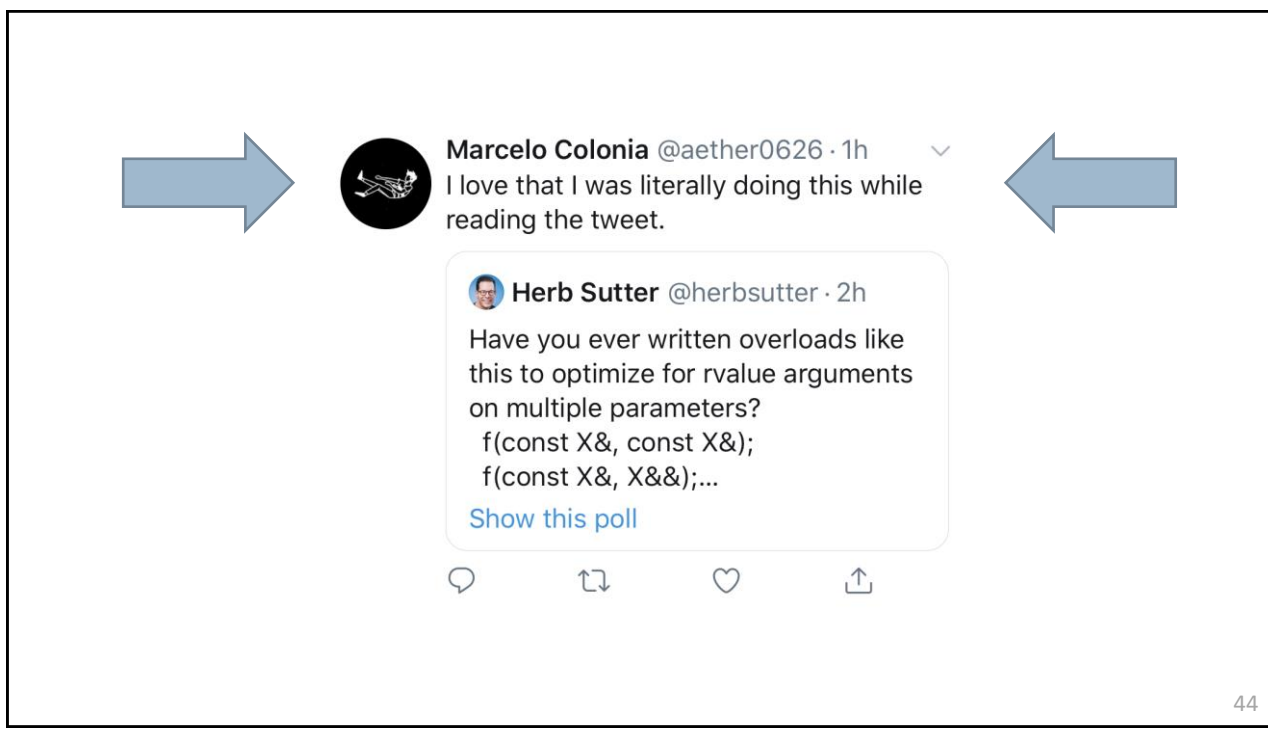
Marcelo Colonia @aether0626 · 1h
I love that I was literally doing this while reading the tweet.
Herb Sutter @herbsutter · 2h
Have you ever written overloads like this to optimize for rvalue arguments on multiple parameters?
f(const X&, const X&);
f(const X&, X&&);...
Show this poll
44

44

"Not gonna" demo… (but: /z/WYWWcf)

```
//----------------------------------------------------------------------------
//  Today's "old" in-parameter implementation -- simple -- three parameters
//----------------------------------------------------------------------------


    // ...
    // Ctrl-C/Ctrl-V and tweak (8 combinations)
    // ...


//----------------------------------------------------------------------------
//  Proposed "new" in-parameter implementation -- simple -- three parameters
//----------------------------------------------------------------------------

void new_in(in String s1, in String s2, in String s3) {
    copy_from(s1, s2, s3);
}
```

45

45

demo-in-4

***Advanced** guidance,*
***template**,*
***one** parameter*

cppx.godbolt.org/z/498MaK

```
//----------------------------------------------------------------------------
//  Today's "old" in-parameter implementation -- advanced -- one parameter
//----------------------------------------------------------------------------

template<typename T> constexpr bool should_pass_by_value_v
    = std::is_trivially_copyable_v<T> && sizeof(T) < 8;

template<typename T>
    requires should_pass_by_value_v<T>
void old_in(T t) {
    copy_from(t);
}

template<typename T>
    requires (!should_pass_by_value_v<T>)
void old_in(const T& t) {
    copy_from(t);
}

template<typename T>
    requires (   !should_pass_by_value_v<T>
              && !std::is_reference_v<T>) // don't grab non-const lvalues
void old_in(T&& t) {
    copy_from(std::forward<T>(t));        // means 'std::move'
}


//----------------------------------------------------------------------------
//  Proposed "new" in-parameter implementation -- advanced -- one parameter
//----------------------------------------------------------------------------

void new_in(in auto t) {
    copy_from(t);
}
```

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"Not gonna" demo…

```
//----------------------------------------------------------------------------
//  Todays "old" in-parameter implementation -- advanced -- three parameters
//----------------------------------------------------------------------------


    // ...
    // choose your own adventure (24 constrained overloads)
    // ...


//----------------------------------------------------------------------------
//  Proposed "new" in-parameter implementation -- advanced -- three parameters
//----------------------------------------------------------------------------

void new_in(in auto x, in auto y, in auto z) {
    copy_from(x, y, z);
}
```

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demo-in-5

***Advanced** guidance, **template**, **N** parameters*

cppx.godbolt.org/z/oxT6aq

```
void new_in(in auto a, in auto b, in auto c, in auto d, in auto e, in auto f) {
    copy_from(a, b);
    copy_from(c);
    copy_from(d, e, f);
}
```

```
    int i = 0;
    String s, s2, s3;
    new_in(i, s, std::move(s2), s3, 42, String());
```

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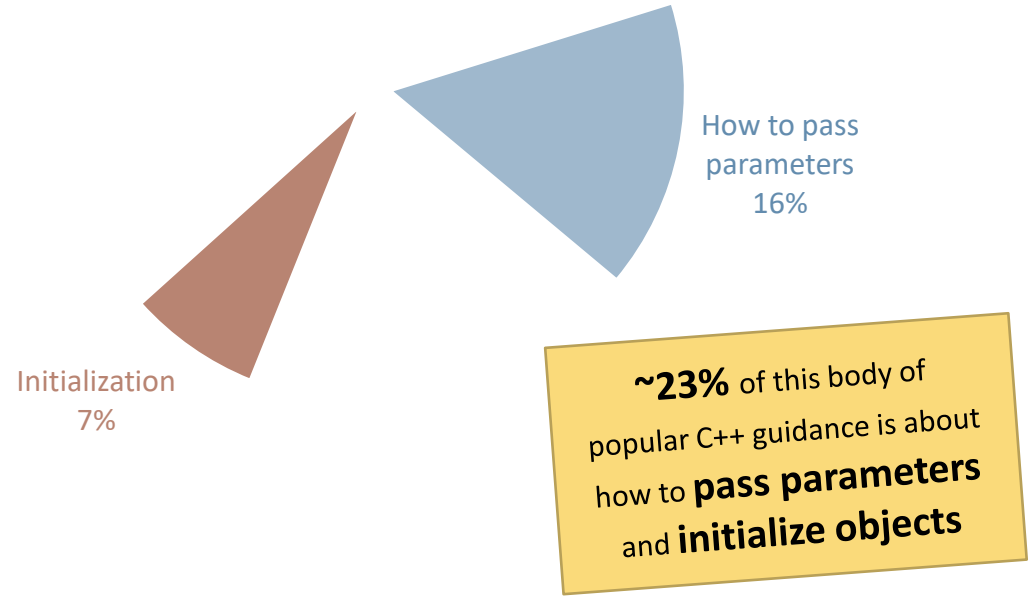

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Initialization: Today's advice

Today's coding guidelines aim for "always initialize **at declaration**":

```
X x = something;
```

Good: When you have a value, which is most of the time.

But they universally add "… **except for** cases like" these:

```
byte buf[1000];                          // classic C
memcpy(&buf[0], src.data(), src.size());

db_format data;                          // any large fixed-layout POD
read_next_chunk(&data);                  // e.g., from disk or network
while (/*...*/) read_next_chunk(&data);
```

Artificial initial values are **unuseful** (overwritten), potentially **expensive** (dead writes), and **error-prone** (hide uninitialized use from UB tools).

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Alternative: Initialize before use

Initialize **before use**.

- Precedent in Ada: Simple enough to teach in "Lesson 2" (*www.functionx.com/ada/Lesson02.htm*).
- Precedent in C#: Enforced, millions of non-expert programmers, no complaints.
- Enables "with **program-meaningful values**."

Advantages:

- Consistent: For all types (non-PODs, small PODs, big PODs).
- Correct: Guarantees initialization before use, with useful values.
- Efficient: No dead writes.
- Bonus: Naturally works for all the understandings of "moved-from" objects to set them to a new known state.

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Earlier on, I simplified slightly when I said…

"Today's C++ can't distinguish 'inout' vs 'out'-only because it has no 'out'-only parameters"

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Here's the complete statement…

"Today's C++ can't distinguish 'inout' vs 'out'-only because it has no 'out'-only parameters" **… except for "*this*" object in a constructor**

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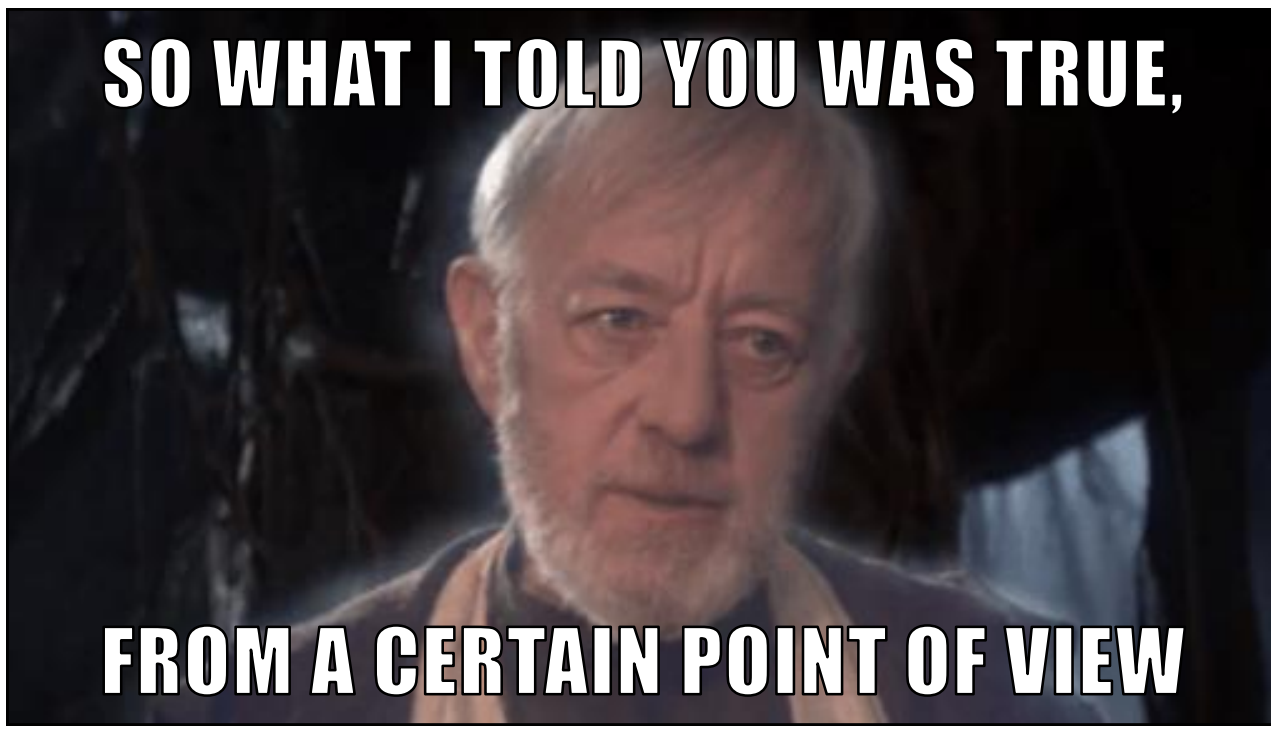

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	in X x	inout X x	out X x	move X x	forward X x
Calling convention	X if cheap to copy, else X*	X*	X*	X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue	Any non-const lvalue	Initialized non-const rvalue	Any object (l- or rvalue)
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)	Every path must have a definite first use, that either assigns to x or passes x to another out param	x is treated as a non-const lvalue Except each definite last use of x treats it as an rvalue and must be to a move parameter	x is treated as a const lvalue Except each definite last use preserves the arg's const-ness and l/r-valueness

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	in X x	inout X x	out X x	move X x	forward X x
Calling convention	X if cheap to copy, else X*	X*	X*	X*	X*
Caller arguments	Initialized object (l- or rvalue)	Initialized non-const lvalue	Uninitialized or non-const lvalue	Initialized non-const rvalue	Any object (l- or rvalue)
Callee uses	x is treated as a const lvalue Except each definite last use preserves the arg's l/rvalue-ness (incl. can move from rvalue arg)	x is treated as a non-const lvalue If function is not virtual, some path must have a non-const use of x (else use in)	Every path must have a definite first use, that either assigns to x or passes x to another out param If x is uninit, constructs	x is treated as a non-const lvalue Except each definite last use of x treats it as an rvalue and must be to a move parameter	x is treated as a const lvalue Except each definite last use preserves the arg's const-ness and l/r-valueness

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"uninitialized" (big POD)

C++20

```
array<byte,N> data; // implicit uninit
while (more_data) {
    get_next_chunk(data); // may fill
    process(data);  // may be uninit
}
```

Proposed equivalent

```
array<byte,N> data /*= uninitialized*/;
while (more_data) {
    get_next_chunk(data); // will fill
    process(data);   // is initialized
}
```

```
void get_next_chunk(array<byte,N>& x)
{
    // don't read from x (not enforced)
    // write to x (not enforced)
    // reading x is now okay
}
```

```
void get_next_chunk(out array<byte,N> x)
{
    // don't read from x (enforced)
    // write to x (enforced)
    // reading x is now okay
}
```

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"uninitialized" (little POD)

C++20

```
int data;  // implicitly uninitialized

get_value(data); // fill (not enforced)

use(data); // no guarantee initialized
```

Proposed equivalent

```
int data /*= uninitialized*/; // (opt.)

get_value(data); // fill data (enforced)

use(data);    // guaranteed initialized
```

```
void get_value(int& i)
{
    // don't read from i (not enforced)
    // write to i (not enforced)
    // reading i is now okay
}
```

```
void get_value(out int i)
{
    // don't read from i (enforced)
    // write to i (enforced)
    // reading i is now okay
}
```

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"uninitialized" (non-POD)

C++20

```
vector<int> data; // default ctor
  // don't read from data (not enforced)
get_value(data);  // fill (not enforced)
  // reading data is now okay
use(data);        // no guarantee filled
```

Proposed equivalent

```
vector<int> data = uninitialized;
  // don't read from data (enforced)
get_value(data); // fill data (enforced)
  // reading data is now okay
use(data);    // guaranteed initialized
```

```
void get_value(vector<int>& v)
{
    // don't read from v (not enforced)
    // write to v (not enforced)
    // reading v is now okay
}
```

```
void get_value(out vector<int> v)
{
    // don't read from v (enforced)
    v = { blah.begin(), blah.end() };
      // write to v (enforced, constructs)
    // reading v is now okay
}
```

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"uninitialized" (non-POD)

C++20

```
db_info dbi; // default ctor required
if (main_site_is_available) {
    get_data(main_site,   dbi);
}           // overwrite default value
else {
    get_data(backup_site, dbi);
}           // overwrite default value
```

Proposed equivalent

```
db_info dbi = uninitialized;
if (main_site_is_available) {
    get_data(main_site,   dbi);
}                       // construct
else {
    get_data(backup_site, dbi);
}                       // construct
```

```
void get_data(const site& s,
              db_info& d) {
    // don't read from d (not enforced)
    // write to d (not enforced)
    // reading d is now okay
}
```

```
void get_data(in site s, out db_info d)
{
    // don't read from d (enforced)
    // write to d (enforced, can construct)
    // reading d is now okay
}
```

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	in X x	inout X x	out X x	move X x	forward X x
Calling convention	X if cheap to copy, else X*	X*	X*	X*	X*
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Upgrade: Declare "what" instead

Declare intent directly:

```
f (        in X x  )    // an X I can read from
f (     inout X x  )    // an X I can read and write
f (       out X x  )    // an X I will assign to
f (      move X x  )    // an X I will move from
f (  forward X x  )    // an X I will pass along
```

That's it… all I'd like to teach about passing parameters in C++.

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Empirical observation:
~23% of this body of popular C++ guidance is about how to **pass parameters** and **initialize objects**
~13% is about how to **write classes** by manual convention

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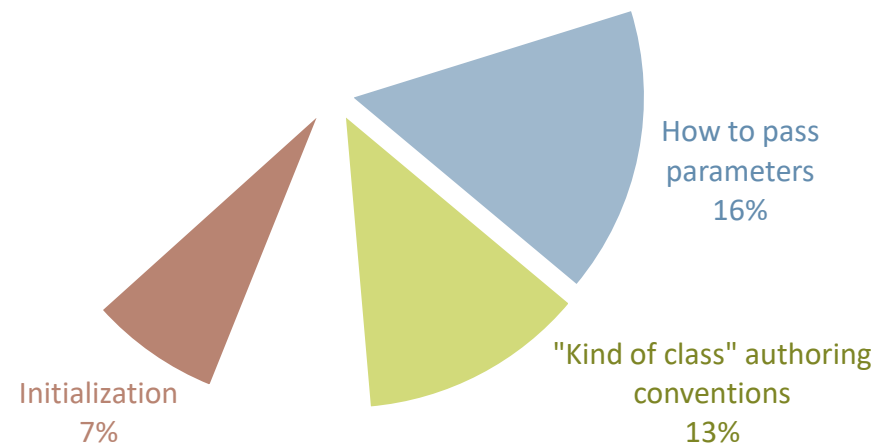
Empirical observation:
~23% of this body of popular C++ guidance is about how to **pass parameters** and **initialize objects**
~13% is about how to **write classes** by manual convention



Estimate: 30% of today's C++ guidelines and coding standards content could be eliminated if we had (and used only) intention-based **parameter passing**, guaranteed program-meaningful **initialization**, and **metaclasses**

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Common claim:
"C++ is too complex"

This talk's contribution:
Empirically catalog, classify, and count

Common despair:
"We can't make things substantially better"

This talk's contribution:
A possible 30% reduction
... 1/3 of the way to 10×

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Resources and teasers

- Where to read more: *github.com/hsutter/**708***
  - Current draft of *d*0708, examples, test cases
- Where to try an in-progress implementation: ***cppx**.godbolt.org*
  - Please file any issues at the repo above

- Teasers (answers in the paper):
  - What would **out this** mean?
  - What would X::operator= taking **in X** mean?
  - What would writing *both* mean?

```
class X {
  // ...
public:
  X& operator=(in X that) out;
};
```

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Simplification: 1..7 of N

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Simplification: 1..7 of N

	1179 (2015-) Lifetime
Simplification	Directly support "owners" and "pointers," eliminate classes of use-after-free/invalid
Prototype	● MSVC, Clang
Product/spec adoption	● Guidelines ● MSVC ○ Clang
WG21 encouraged	n/a
Next steps	Continue Clang upstreaming (& WG21?)

***cppx**.godbolt.org*

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Simplification: 1..7 of N

	1179 (2015-) Lifetime	0515 (2017-) <=> Comparison
Simplification	Directly support "owners" and "pointers," eliminate classes of use-after-free/invalid	Directly express comparison intent, eliminate boilerplate & errors
Prototype	● MSVC, Clang	
	***cppx**.godbolt.org*	
Product/spec adoption	● Guidelines ● MSVC ○ Clang	● C++20 (incl. std:: lib)
WG21 encouraged	n/a	●
Next steps	Continue Clang upstreaming (& WG21?)	

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Simplification: 1..7 of N

	1179 (2015-) Lifetime	0515 (2017-) <=> Comparison	0707 (2017-) Metaclasses
Simplification	Directly support "owners" and "pointers," eliminate classes of use-after-free/invalid	Directly express comparison intent, eliminate boilerplate & errors	Directly express class authoring intent, eliminate boilerplate & errors
Prototype	● MSVC, Clang		● Clang
	***cppx**.godbolt.org*		
Product/spec adoption	● Guidelines ● MSVC ○ Clang	● C++20 (incl. std:: lib)	
WG21 encouraged	n/a	●	○
Next steps	Continue Clang upstreaming (& WG21?)		C++2x reflection & consteval programming

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Simplification: 1..7 of N

	1179 (2015-) Lifetime	0515 (2017-) <=> Comparison	0707 (2017-) Metaclasses	0709 (2018-) Static EH
Simplification	Directly support "owners" and "pointers," eliminate classes of use-after-free/invalid	Directly express comparison intent, eliminate boilerplate & errors	Directly express class authoring intent, eliminate boilerplate & errors	Eliminate largest fracture in C++ usage/libs
Prototype	● MSVC, Clang		● Clang	
			***cppx**.godbolt.org*	
Product/spec adoption	● Guidelines ● MSVC ○ Clang	● C++20 (incl. std:: lib)		
WG21 encouraged	n/a	●	○	○
Next steps	Continue Clang upstreaming (& WG21?)		C++2x reflection & consteval programming	Prototype

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Simplification: 1..7 of N

	1179 (2015-) Lifetime	0515 (2017-) <=> Comparison	0707 (2017-) Metaclasses	0709 (2018-) Static EH	0708 (2020-) Parameters
Simplification	Directly support "owners" and "pointers," eliminate classes of use-after-free/invalid	Directly express comparison intent, eliminate boilerplate & errors	Directly express class authoring intent, eliminate boilerplate & errors	Eliminate largest fracture in C++ usage/libs	Directly express param intent, eliminate boilerplate, guaranteed unified init
Prototype	● MSVC, Clang		● Clang		○ Clang
			***cppx**.godbolt.org*		
Product/spec adoption	● Guidelines ● MSVC ○ Clang	● C++20 (incl. std:: lib)			
WG21 encouraged	n/a	●	○	○	
Next steps	Continue Clang upstreaming (& WG21?)		C++2x reflection & consteval programming	Prototype	Finish prototype WG21 (when face-to-face)

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"Efficient abstraction" – in that order!

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"Efficient abstraction" – in that order!

Don't design an abstraction, *then* try to make it efficient

- Examples: Smalltalk classes, C++0x concepts

Do learn from "what we already do." For important abstractions,

- **"efficient"** way we've already learned to implement them (but by hand)
- **then "abstraction"** to let us directly express intent (and automate it!)
- Examples: vtables (since C!), metaclasses, by-value EH, parameters

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