

Debug C++ Without Running

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CppCon 2018

Agenda

1. Why this talk? Tricky C++.
2. Classic solution: debugger, static/dynamic analyzer.
3. How an IDE can help?

Agenda

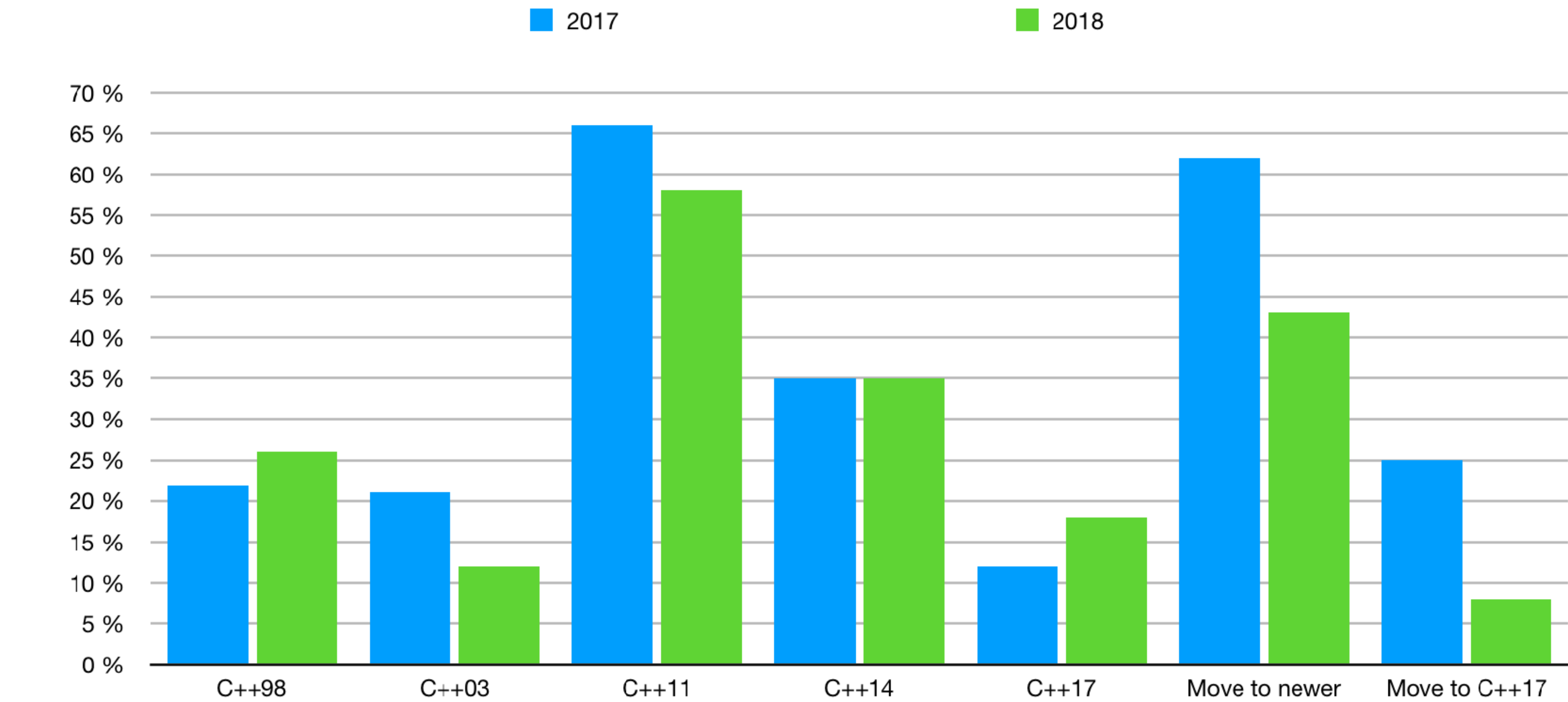
1. Why this talk? Tricky C++.
2. Classic solution: debugger, static/dynamic analyzer.
3. How an IDE can help?

Time for a quote

*“C makes it easy to shoot yourself in the foot;
C++ makes it harder, but when you do it blows your whole leg off”
- Bjarne Stroustrup*

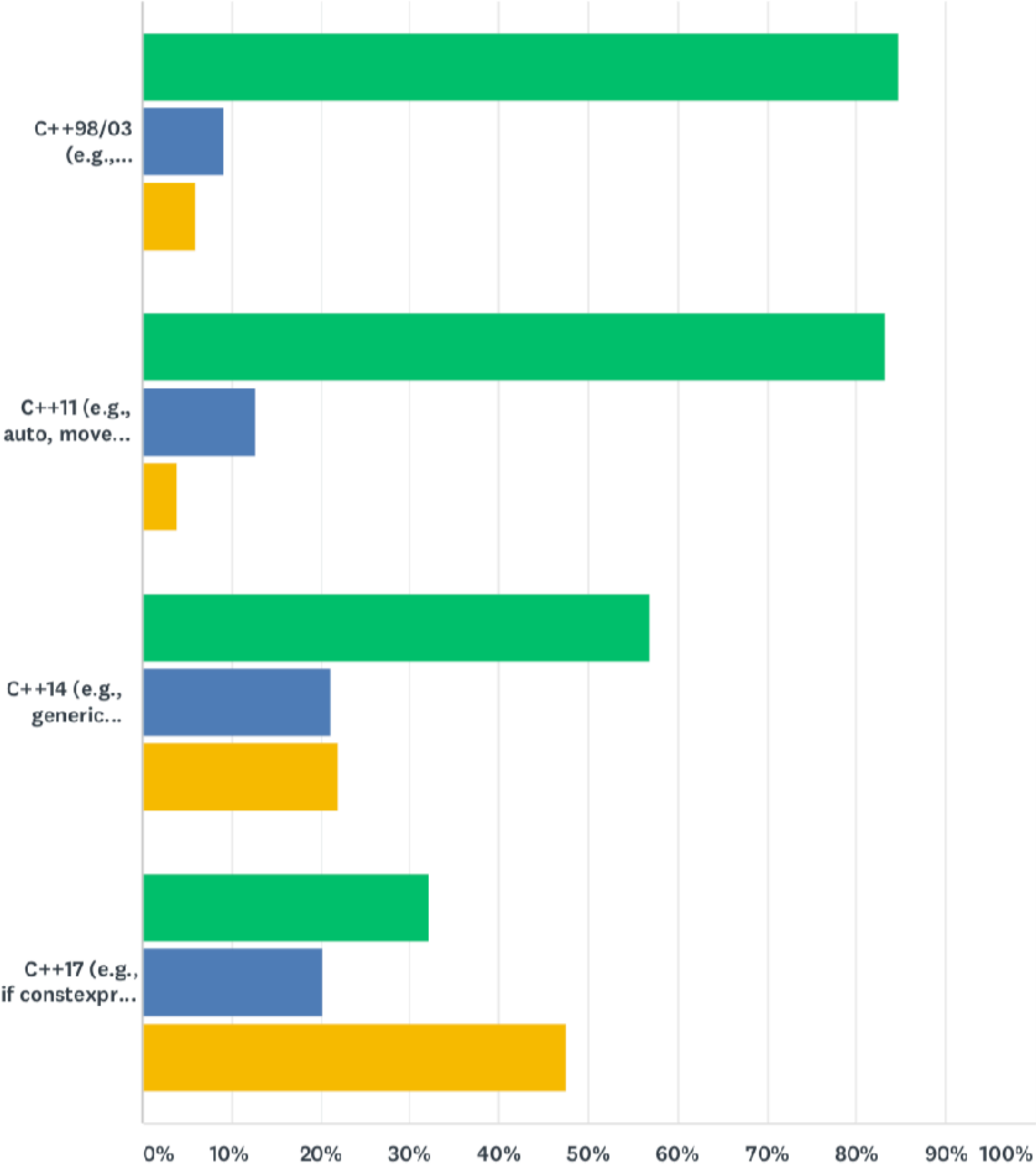
http://www.stroustrup.com/bs_faq.html#really-say-that

JetBrains Dev Ecosystem survey 2017/2018



C++ Foundation Developer Survey 2018

Constexpr Edge References Resources Toolchain Impossible
Practices MSVC Learn Nope Code Modules Compiler
Hard to Understand New Features Colleagues
Standard Amount Language Tools Difficulty Evolves
New Stuff Dependencies Older Past Books Difficult to Understand



C++ difficulties: 42

—

```
template<class T, int ... X>  
T pi(T(X...));
```

```
int main() {  
    return pi<int, 42>;  
}
```


C++ difficulties: 42

```
template<class T, int ... X>  
T pi(T(X...));
```

```
int main() {  
    return pi<int, 42>;  
}
```

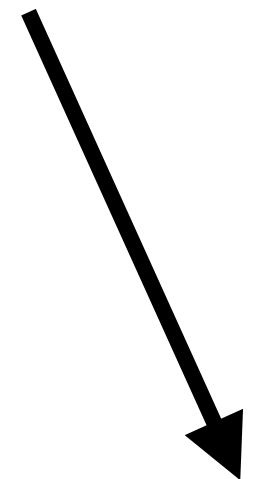
```
x86-64 gcc 7.3 (Editor #1, Compiler #1) C++ x  
x86-64 gcc 7.3 -std=c++14  
A 11010 .LX0: .text // \s+ Intel Demangle Libraries + Add new...  
1 main:  
2     push    rbp  
3     mov     rbp, rsp  
4     mov     eax, DWORD PTR pi<int, 42>[rip]  
5     pop     rbp  
6     ret  
7 pi<int, 42>:  
8     .long   42
```

```
x86-64 clang 6.0.0 (Editor #1, Compiler #1) C++ x  
x86-64 clang 6.0.0 -std=c++14  
A 11010 .LX0: .text // \s+ Intel Demangle Libraries + Add new...  
1 main: # @main  
2     push    rbp  
3     mov     rbp, rsp  
4     mov     dword ptr [rbp - 4], 0  
5     mov     eax, dword ptr [pi<int, 42>]  
6     pop     rbp  
7     ret  
8 pi<int, 42>:  
9     .long   42 # 0x2a
```


C++ difficulties: 42

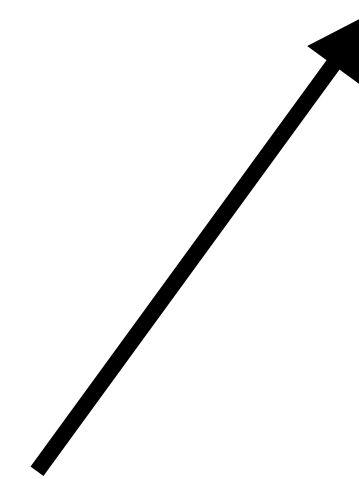
```
template<class T, int ... X>
T pi(T(X...));
```

```
int main() {
    return pi<int, 42>;
}
```

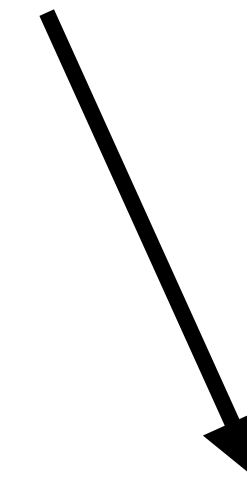


```
template<class T, int ... X>
T pi = T(X...);
```

```
int main() {
    return pi<int, 42>;
}
```



```
int main() {
    return int(42);
}
```



```
int main() {
    return 42;
}
```

C++ difficulties: macro

```
#define X(a) myVal_##a,  
enum myShinyEnum {  
#include "xmacro.txt"  
};  
#undef X  
  
void foo(myShinyEnum en) {  
    switch (en) {  
        case myVal_a:break;  
        case myVal_b:break;  
        case myVal_c:break;  
        case myVal_d:break;  
    }  
}
```

//xmacro.txt

X(a)
X(b)
X(c)
X(d)

C++ difficulties: macro

```
#define MAGIC 100
#define CALL_DEF(val, class_name) int call_##class_name() \
                                   { return val; }

#define CLASS_DEF(class_name) class class_##class_name { \
                               public: \
                                   int count_##class_name; \
                                   CALL_DEF(MAGIC, class_name) \
                               };
```

```
CLASS_DEF(A)
CLASS_DEF(B)
CLASS_DEF(C)
```

C++ difficulties: context

```
//foo.h
#ifdef MAGIC
template<int>
struct x {
    x(int i) { }
};
#else
int x = 100;
#endif
```

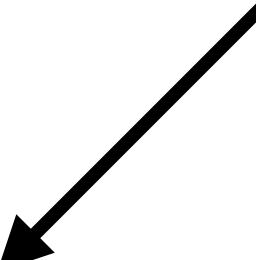
```
//foo.cpp
#include "foo.h"
void test(int y) {
    const int a = 100;

    auto k = x<a>(0);
}
```

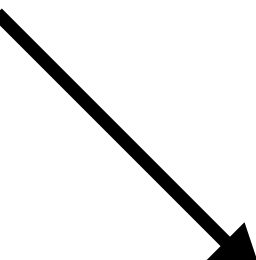
C++ difficulties: compile-time generation

```
$class interface {  
    constexpr {  
        compiler.require($interface.variables().empty(),  
                          "interfaces may not contain data");  
        for... (auto f : $interface.functions()) {  
            compiler.require(!f.is_copy() && !f.is_move(),  
                             "interfaces may not copy or move; consider a"  
                             " virtual clone() instead");  
            if (!f.has_access()) f.make_public();  
            compiler.require(f.is_public(),  
                             "interface functions must be public");  
            f.make_pure_virtual();  
        }  
    }  
    virtual ~interface() noexcept { }  
};
```

```
interface Shape {  
    int area() const;  
    void scale_by(double factor);  
};
```



```
struct Shape {  
    virtual int area() const = 0;  
    virtual void scale_by(double factor) = 0;  
    virtual ~Shape() noexcept {  
    }  
}
```



C++ difficulties: overloads

```
class Fraction {...};

std::ostream& operator<<(std::ostream& out, const Fraction& f){...}

bool operator==(const Fraction& lhs, const Fraction& rhs){...}

bool operator!=(const Fraction& lhs, const Fraction& rhs){...}

Fraction operator*(Fraction lhs, const Fraction& rhs){...}

void fraction_sample()
{
    Fraction f1(3, 8), f2(1, 2);

    std::cout << f1 << " * " << f2 << " = " << f1 * f2 << '\n';
}
```


C++ difficulties: overloads

```
void foo() { std::cout << "1\n"; }
void foo(int) { std::cout << "2\n"; }
template<typename T> void foo(T) { std::cout << "3\n"; }
template<> void foo(int) { std::cout << "4\n"; }
template<typename T> void foo(T*) { std::cout << "5\n"; }
struct S {};
void foo(S) { std::cout << "6\n"; }
struct ConvertibleToInt {ConvertibleToInt(int); };
void foo(ConvertibleToInt) { std::cout << "7\n"; }
namespace N {
    namespace M { void foo(char) { std::cout << "8\n"; } }
    void foo(double) { std::cout << "9\n"; }
}

int main() {
    foo(1);

    using namespace N::M;
    foo(1);
}
```

C++ difficulties: even more

—

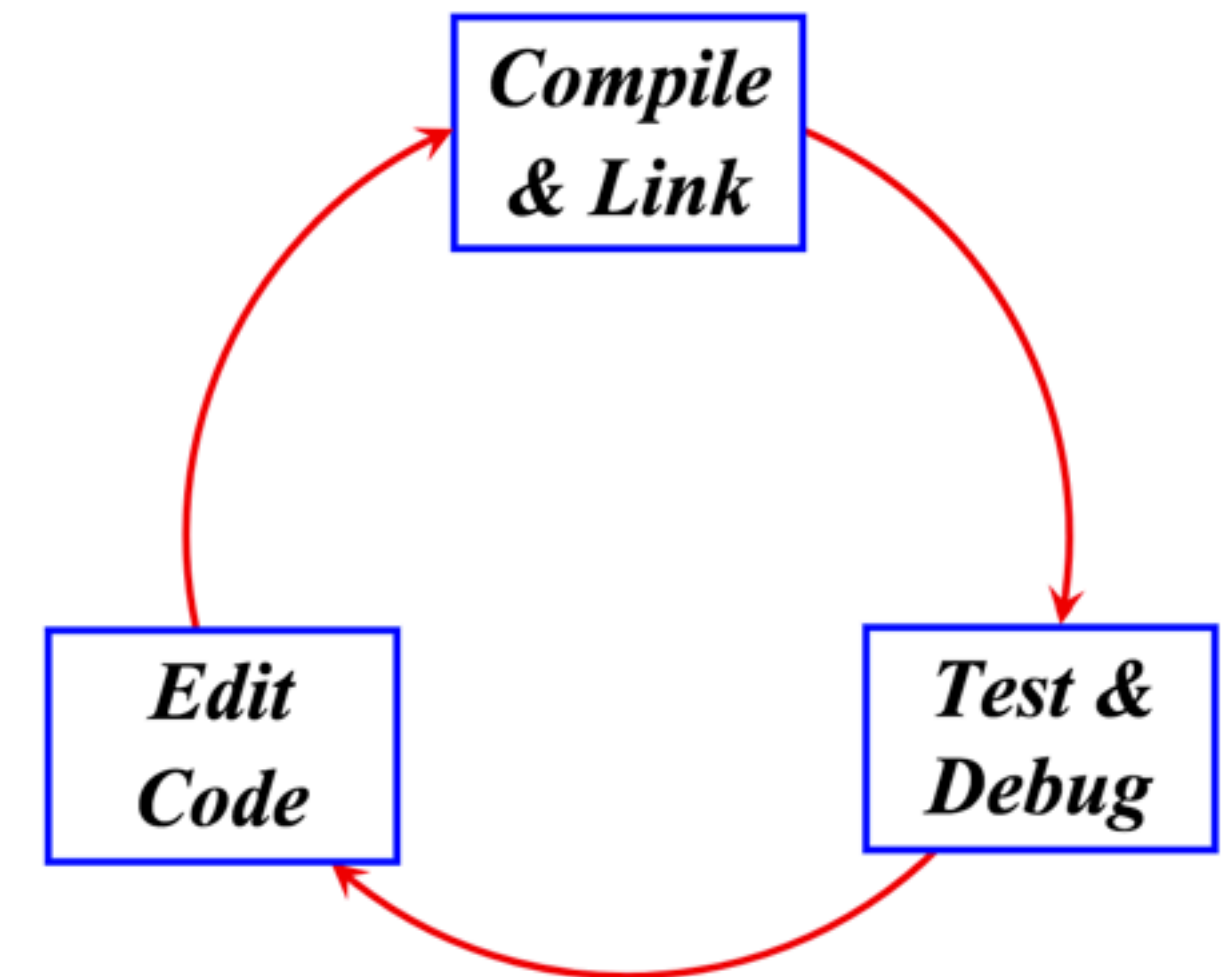
- Constexpr
- Injected code
- ...

Agenda

1. Why this talk? Tricky C++.
2. Classic solution: debugger, static/dynamic analyzer.
3. How an IDE can help?

Do these help?

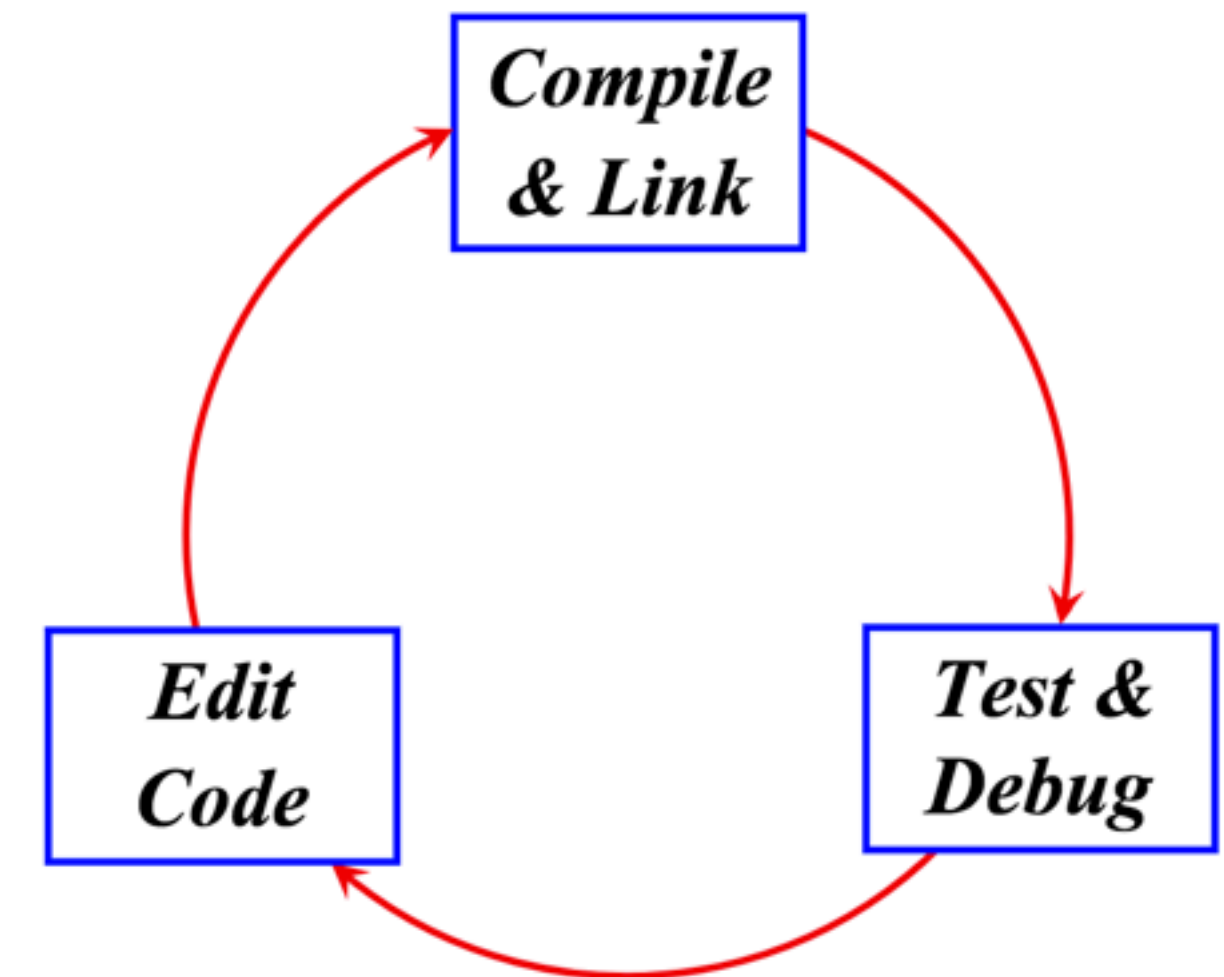
- Read-fix-run / read-fix-print-run and check results
- Debug
- Use static or dynamic code analysis



Do these help?

- Read-fix-run / read-fix-print-run and check results
- Debug
- Use static or dynamic code analysis

No!
(not always)



Herb Sutter's keynotes CppCon'17

Meta - Thoughts on Generative C++

- Abstractions are hiders
- Abstractions need tool support
- Good abstractions do need to be toolable

Herb Sutter's keynotes CppCon'17

⇒ Abstractions need **tool** support.

C

Variables: hide values ⇒ need watch windows (debug)

Functions: hide code ⇒ need Go To Definition (IDE) / Step Into (debug)

Pointers: hide indirection ⇒ need visualizers (debug)

#includes: hide dependencies ⇒ need file “touch”-aware build (build)

C++98

Classes: hide code/data, encapsulate behavior ⇒ need most of the above

Overloads: hide static polymorphism ⇒ need better warning/error msgs

Virtuals: hide dynamic polymorphism ⇒ need dynamic debug support

C++17

constexpr functions: hide computations ⇒ need compile-time debug

if constexpr: hide whether code even has to compile ⇒ need colorizers

Modules: hide dependencies ⇒ need module “touch”-aware build (build)

proposed

Compile-time variables: hide values ⇒ need compile-time watch

Compile-time code/functions: hide computation ⇒ need compile-time debug

Injection, metaclasses: generate entities ⇒ need to visualize them

Agenda

1. Why this talk? Tricky C++.
2. Classic solution: debugger, static/dynamic analyzer.
3. How an IDE can help?

The power of tools:

Macro debug

Goal – *understand the substitution w/o running the preprocessor*

The power of tools: Macro debug

Existing options:

- Show final replacement

```
#define MAGIC 100
#define CALL_DEF(val, class_name) int call_##class_name() { return val; }

#define CLASS_DEF(class_name) class class_##class_name { \
    public: \
        int count_##class_name; \
        CALL_DEF(MAGIC, class_name) \
};
```

```
CLASS_DEF(A)
CLASS_DEF(B)
CLASS_DEF(C)
```

Declared In: MacroReplacement.cpp

Definition:

```
#define CLASS_DEF(class_name) class class_##class_name { \
    public: \
        int count_##class_name; \
        CALL_DEF(MAGIC, class_name) \
};
```

Replacement:

```
class class_C {
public:
    int count_C;
    int call_C() { return 100; }
};
```



The power of tools: Macro debug

Existing options:

- Show final replacement
- Substitute next step

```
#define MAGIC 100
#define CALL_DEF(val, class_name) int call_##class_name() { return val; }
```

```
▢ #define CLASS_DEF(class_name) class class_##class_name { \
    |                                     public: \
    |                                     int count_##class_name; \
    |                                     CALL_DEF(MAGIC, class_name) \
    |                                     };
```

```
class class_A { public: int count_A; CALL_DEF(MAGIC, A) };
CLASS_DEF(B)
CLASS_DEF(C)
```

The power of tools: Macro debug

Existing options:

- Show final replacement
- Substitute next step
- Substitute all steps

```
#define MAGIC 100
#define CALL_DEF(val, class_name) int call_##class_name() { return val; }
```

```
▢ #define CLASS_DEF(class_name) class class_##class_name { \
    |                                     public: \
    |                                     int count_##class_name; \
    |                                     CALL_DEF(MAGIC, class_name) \
    |                                     };
```

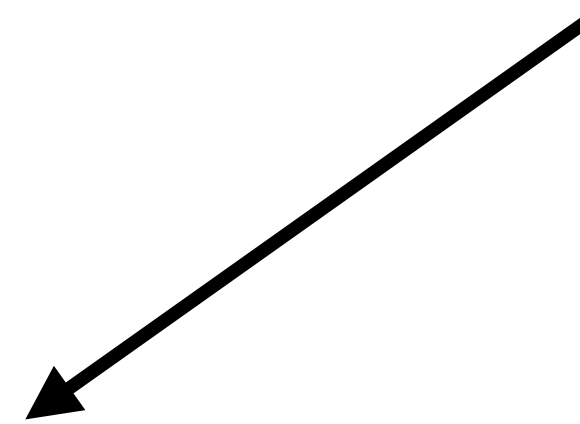
```
class class_A { public: int count_A; int call_A() { return 100; } };
CLASS_DEF(B)
CLASS_DEF(C)
```


The power of tools: Macro debug

Substitute macro – practical sample

```
#define DECL(z, n, text) text ## n = n;
```

```
BOOST_PP_REPEAT(5, DECL, int x)
```



```
#define DECL(z, n, text) text ## n = n;
```

```
BOOST_PP_CAT(BOOST_PP_REPEAT_, BOOST_PP_AUTO_REC(BOOST_PP_REPEAT_P, 4))(5, DECL, int x)
```

```
#define DECL(z, n, text) text ## n = n;
```

```
int x0 = 0; int x1 = 1; int x2 = 2; int x3 = 3; int x4 = 4;
```



████████████████████

Code might be affected!

```
#define __NEW_VAR(name, num) static void *__v_##num = (void *)&name
#define _NEW_VAR(name, num) __NEW_VAR(name, num)
#define NEW_VAR(name) _NEW_VAR(name, __COUNTER__)
```

```
void counter_macro_sample() {  
    NEW_VAR(v);  
    NEW_VAR(v);  
    NEW_VAR(v);  
}
```

The power of tools: Macro debug

Be careful!

Code might be affected!

```
static int v;
```

```
#define __NEW_VAR(name, num) static void *__v_##num = (void *)&name  
#define _NEW_VAR(name, num) __NEW_VAR(name, num)  
#define NEW_VAR(name) _NEW_VAR(name, __COUNTER__)
```

```
void counter_macro_sample() {  
    NEW_VAR(v);  
    static void *__v_1 = (void *)&v;  
    NEW_VAR(v);  
}
```

The power of tools: Macro debug

Macro debug requires
all usages analysis!

```
void func(int i) {}  
void func(double d) {}
```

```
#define FUNCM func
```

```
void macro_definition_usage() {  
    FUNCM(0);  
    FUNCM(0.0);  
  
    int func;  
    FUNCM;  
}
```


The power of tools: Macro debug



Macro debug requires
all usages analysis!

```
void func(int i) {}  
void func(double d) {}
```

```
#define FUNCM func
```

```
void macro_defin  
{  
    FUNCM(0);  
    FUNCM(0.0);  
  
    int func;  
    FUNCM;  
}
```

Declaration of identifier 'func' 

	func(int i): void	DebugNoRunDemo.cpp
	func(double d): void	DebugNoRunDemo.cpp

The power of tools:

Type info debug

—

Goal – *understand the final type*

The power of tools:

Type info debug

Existing options:

- Show inferred type

```
template<typename T, typename U>
auto doOperation(T t, U u) -> decltype(t + u) {
    return t + u;
}

void fun_type() {
    auto op = doOperation(3.0, 0);
    //...
}
```

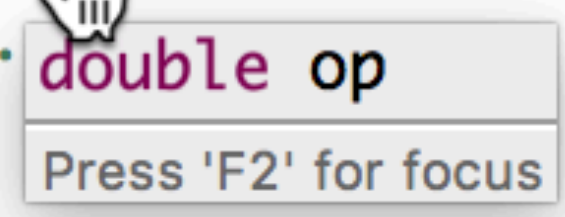
The power of tools:

Type info debug

Existing options:

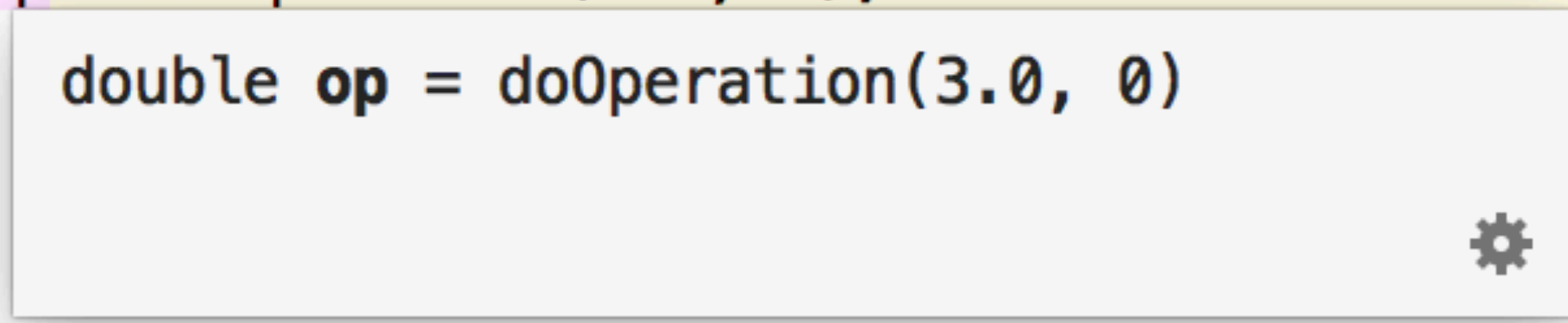
- Show inferred type

```
14 template<typename T, typename U>
15 auto doOperation(T t, U u) -> decltype(t + u) {
16     return t + u;
17 }
18
19 void fun_type() {
20     auto op = doOperation(3.0, 0);
21     //... double op
22 }
23
24
```



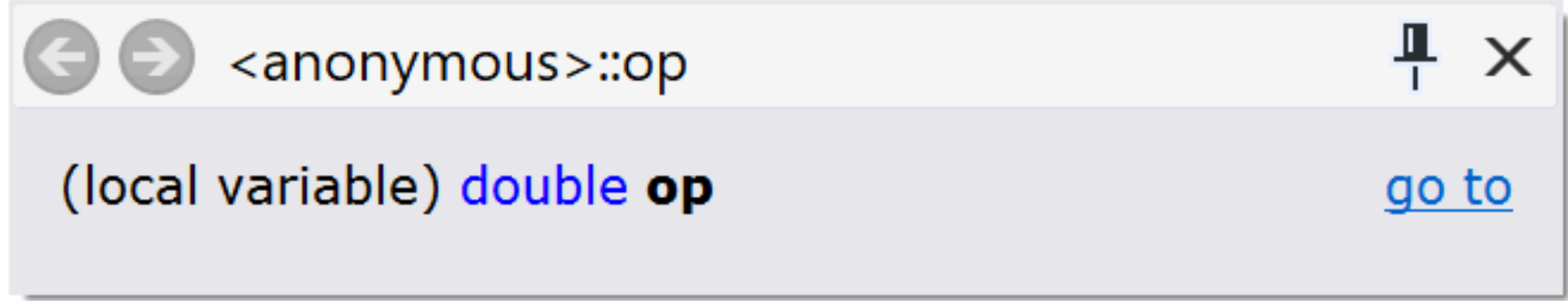
```
template<typename T, typename U>
auto doOperation(T t, U u) -> decltype(t + u) {
    return t + u;
}
```

```
void fun_type() {
    auto op = doOperation(3.0, 0);
    //... double op = doOperation(3.0, 0)
}
```



```
template<typename T, typename U>
auto doOperation(T t, U u) -> decltype(t + u) {
    return t + u;
}
```

```
void fun_type() {
    auto op = doOperation(3.0, 0);
    //... <anonymous>::op
}
```



The power of tools:

Type info debug

Existing options:

- Show inferred type
- Substitute typedef (one step)

```
#define MY_STRUCT(name) struct name {};
```

```
MY_STRUCT(A)
```

```
MY_STRUCT(B)
```

```
MY_STRUCT(C)
```

```
MY_STRUCT(D)
```

```
MY_STRUCT(E)
```

```
typedef boost::mpl::vector<A, B, C, D, E> myStructVec;
```

```
boost::mpl::at_c<myStructVec, 3>::type hi;
```

The power of tools: Type info debug

Existing options:

- Show inferred type
- Substitute typedef (one step)

```
#define MY_STRUCT(name) struct name {};
```

```
MY_STRUCT(A)
```

```
MY_STRUCT(B)
```

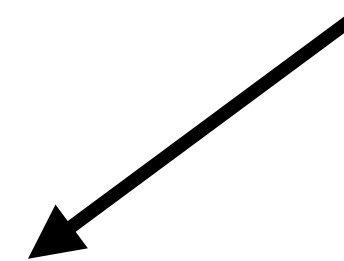
```
MY_STRUCT(C)
```

```
MY_STRUCT(D)
```

```
MY_STRUCT(E)
```

```
typedef boost::mpl::vector<A, B, C, D, E> myStructVec;
```

```
boost::mpl::at_c<myStructVec, 3>::type hi;
```



```
boost::mpl::vector5<A, B, C, D, E>::item3 hi;
```

The power of tools: Type info debug

Existing options:

- Show inferred type
- Substitute typedef (one step)
- Substitute typedef and all nested (all steps)

```
#define MY_STRUCT(name) struct name {};
```

```
MY_STRUCT(A)
```

```
MY_STRUCT(B)
```


```
MY_STRUCT(C)
```

```
MY_STRUCT(D)
```

```
MY_STRUCT(E)
```

```
typedef boost::mpl::vector<A, B, C, D, E> myStructVec;
```

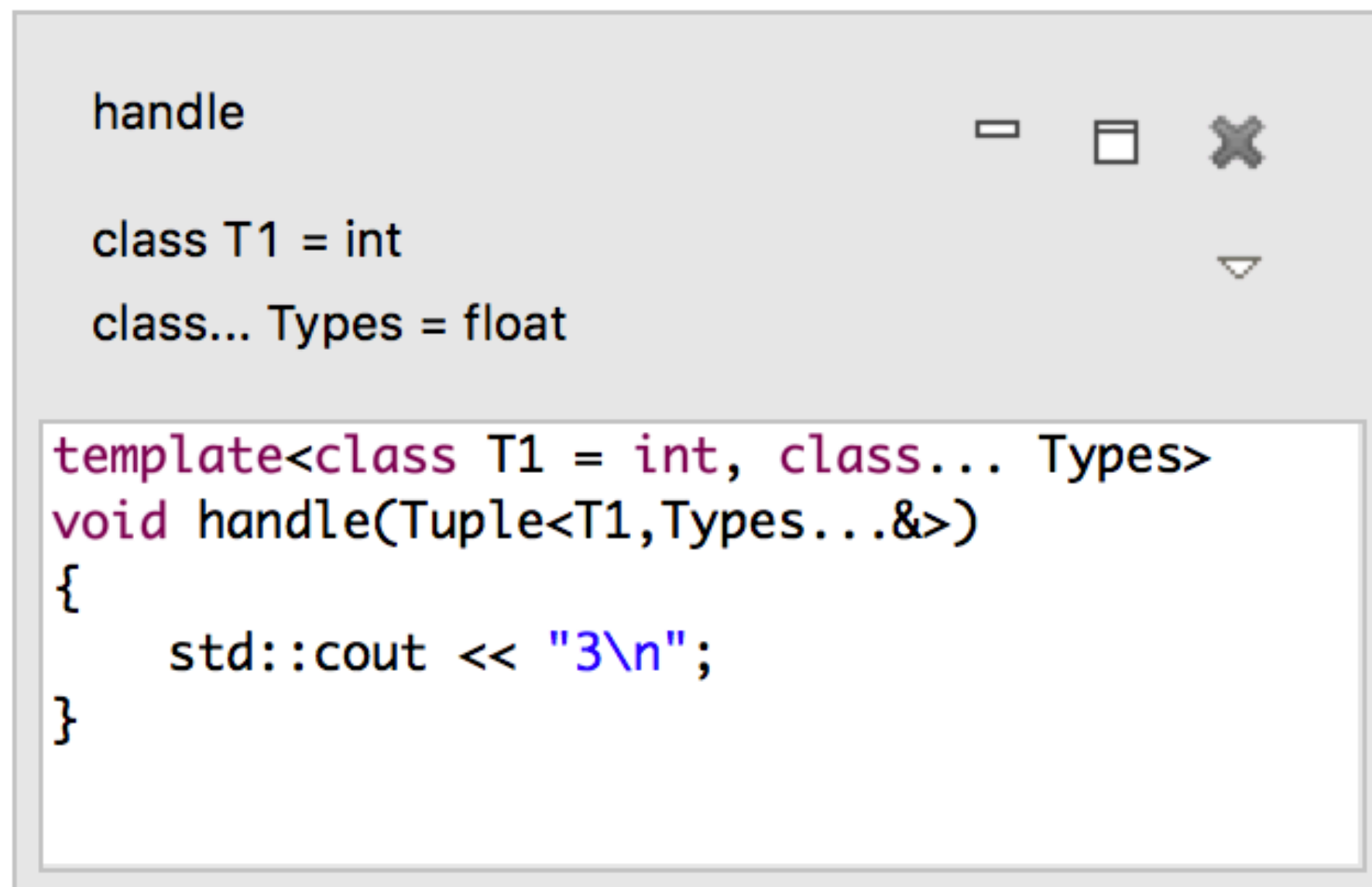
```
boost::mpl::at_c<myStructVec, 3>::type hi;
```


boost::mpl::vector5<A, B, C, D, E>::item3 hi; D hi;

The power of tools: Meta info debug

Debug the abstractions

- Instantiating templates

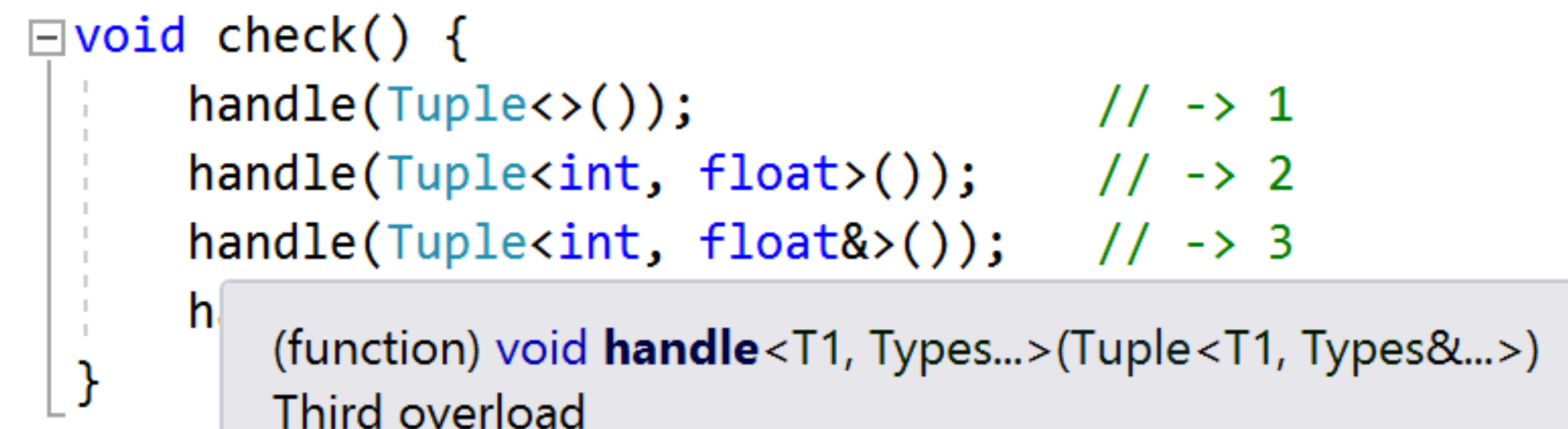


A screenshot of a debugger window titled "handle". The window shows the instantiation of a template function. The top part of the window displays the template parameters: "class T1 = int" and "class... Types = float". Below this, the function signature is shown: "template<class T1 = int, class... Types> void handle(Tuple<T1, Types...&>)". The function body is also visible, showing "std::cout << \"3\\n\";".

```
template<class...> struct Tuple { };  
///First overload  
template<class... Types>  
void handle(Tuple<Types ...>) { std::cout << "1\\n"; }  
///Second overload  
template<class T1, class... Types>  
void handle(Tuple<T1, Types ...>) { std::cout << "2\\n"; }  
///Third overload  
template<class T1, class... Types>  
void handle(Tuple<T1, Types& ...>) { std::cout << "3\\n"; }
```

```
void check() {  
    handle(Tuple<>());           // -> 1  
    handle(Tuple<int, float>()); // -> 2  
    handle(Tuple<int, float&>()); // -> 3  
    //Third overload  
    template<class T1, class... Types>  
    void handle(Tuple<T1, Types& ...>) { std::cout << "3\\n"; }  
}
```

Press 'F2' for focus



A screenshot of a debugger window showing the function signature of the third overload. The window displays the function signature: "void check() { handle(Tuple<int, float&>()); // -> 3". Below the function signature, the function body is visible, showing "std::cout << \"3\\n\";".

The power of tools:

Meta info debug

Debug the abstractions

- Instantiating templates
- Constexpr evaluator

```
template <typename T>
auto get_value(T t) {
    if constexpr (std::is_pointer<T>::value)
        return *t;
    else
        return t;
}

void test()
{
    auto pi = std::make_unique<int>(9);
    int i = 9;

    std::cout << get_value(pi.get()) << "\n";
    std::cout << get_value(i) << "\n";
}
```

The power of tools: Meta info debug

Debug the abstractions

- Instantiating templates
- Constexpr evaluator
- Template intellisense

```
2
3  template<typename ITER> <T>
4  void kadane(
5      const ITER& input_begin,
6      const ITER& input_end,
7      std::pair<ITER, ITER>& output_range,
8      typename std::iterator_traits<ITER>::value_type& output_value)
9  {
10     typedef typename std::iterator_traits<ITER>::value_type
11         ValueType;
12
13     ITER begin, begin_temp, end;
14     ValueType max_so_far{};
15     ValueType max_ending_here{};
16
17     begin = input_begin;
18     begin_temp = input_begin;
19     end = input_begin;
20
21     // Holds the frontier value of K[i-1].
```

100 %

Ready Ln 16 Col 5 Ch 2 INS

The power of tools:

Overloads debug

—

Debug functions and operators overload

The power of tools:

Overloads debug

Debug overloads:

- Distinguish overloaded operators

```
class Fraction {...};
```

```
std::ostream& operator<<(std::ostream& out, const Fraction& f)
{
    return out << f.num() << '/' << f.den() ;
}
```

```
bool operator==(const Fraction& lhs, const Fraction& rhs)
{...}
```

```
bool operator!=(const Fraction& lhs, const Fraction& rhs)
{...}
```

```
Fraction operator*(Fraction lhs, const Fraction& rhs)
{...}
```

```
void fraction_sample()
{
```

```
    Fraction f1(3, 8), f2(1, 2);
```

```
    std::cout << f1 << " * " << f2 << " = " << f1 * f2 << '\n';
```

```
}
```

The power of tools:

Overloads debug

Debug overloads:

- Distinguish overloaded operators
- Explain overload resolution

Overload resolution:

1. Do name lookup
2. Do template argument deduction
3. Pick the candidate
4. Check access control

The power of tools:

Overloads debug

Show candidates set via
parameter info

- One-by-one or all together
- Parameters or full signature

```
int main() {  
    foo(1);  
}
```

▲ 6 of 8 ▼ void foo<int>(int)

```
void foo() { std::cout << "1\n"; }  
void foo(int) { std::cout << "2\n"; }  
template<typename T> void foo(T) { std::cout << "3\n"; }  
template<> void foo(int) { std::cout << "4\n"; }  
struct S {};  
void foo(S) { std::cout << "5\n"; }  
struct ConvertibleToInt {ConvertibleToInt(int) {} };  
int foo(ConvertibleToInt) { std::cout << "6\n"; return 0; }  
namespace N {  
    namespace M { void foo(char) { std::cout << "7\n"; } }  
    void foo(double) { std::cout << "8\n"; }  
}
```

```
void foo (int a, int b);  
void foo (int a, double b);  
void foo (int a, ConvertibleToInt b);
```

<no parameters>
int
T
S
ConvertibleToInt
int a, int b
int a, double b
int a, ConvertibleToInt b

```
int main() {  
    foo(1);  
}
```

The power of tools: Overloads debug

Show candidates set via
parameter info

- One-by-one or all together
- Parameters or full signature

```
int main() {  
    foo(1);  
}
```

- foo(void) : void
- foo(int) : void
- foo(T) : void
- foo(S) : void
- foo(ConvertibleToInt) : int

```
void f(<no parameters>): void  
void f(int): void  
void f(foo function  
      (S): void  
      (ConvertibleToInt): int  
      (int a, int b): void  
int main() {  
    foo(1);  
}
```

=delete;
leToInt b) {}

The power of tools: Overloads debug

- Show candidates set
- Show explanations



The power of tools: Overloads debug

Debug overloads:

- Distinguish overloaded operators
- Explain overload resolution
- Navigate to similar functions

```
main.cpp x
1 struct S {
2     void foo() const;
3
4     void bar(int i);
5     void bar(int i, int j);
6     void bar(int i, int j, int k);
7 };
8
9 void S::foo() const {
10
11 }
12
13 void S::bar(int i) {
14
15 }
16
17 void S::bar(int i, int j) {
18
19 }
20
21 void S::bar(int i, int j, int k) {
22
23 }
24
```

The power of tools: Includes profiler

“Once an #include has been added, it stays”
(<http://bitsquid.blogspot.co.uk/2011/10/caring-by-sharing-header-hero.html>)

Blowup factor = total lines / total lines parsed



The power of tools: Includes profiler

—

Header heros:

- PCH












The power of tools:

Includes profiler

—

Header heros:

- PCH
- Profilers

Includes profile of solution 'debuggerext'  			
Type to search			
Includee file	Times included	Line contribution	Line contribution inclusive ▼
 debuggerext.cpp (debuggerext)	1	599	2675
▶  EventCallback.h (debuggerext)	3	294	1359
 EventCallback.cpp (debuggerext)	1	279	1070
▲  DebugContext.h (debuggerext)	13	892	892
 StackTrace.cpp (debuggerext)	1	223	223
 debuggerext.cpp (debuggerext)	1	223	223
▶  OutputCallback.h (debuggerext)	2	223	223
▶  EventCallback.h (debuggerext)	2	223	223
▶  StackTrace.h (debuggerext)	2	0	0

The power of tools: Includes profiler

Header heros:

- PCH
- Profilers
- Optimizers
 - Unused include check
 - Include what you use (and don't include what you don't use)
 - Includator

References

- Herb Sutter, Meta - Thoughts on Generative C++
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- C++ Foundation Developer Survey
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 - [2017] <https://www.jetbrains.com/research/devecosystem-2017/cpp/>
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**Thank you
for your attention**

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Questions?