

Debug C++ Without Running

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++It 2018

Agenda

1. Tricky C++ language. Show samples!
2. Seems to help but it doesn't. Why?
 - Running / Debugging
 - Static / dynamic code analysis
3. Should help – IDEs! How?

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1. Tricky C++ language. Show samples!
2. Seems to help but it doesn't. Why?
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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

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>;  
}
```

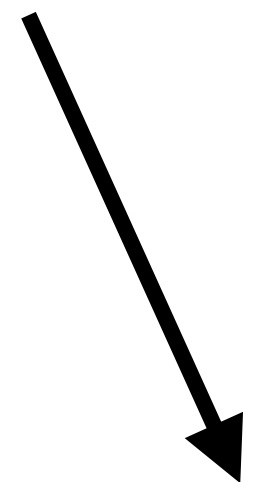
```
x86-64 gcc 7.3 (Editor #1, Compiler #1) C++ x  
x86-64 gcc 7.3 -std=c++14  
A 11010 .LX0: .text // \s+ Intel Demangle Libraries + Add new...  
1 main:  
2     push    rbp  
3     mov     rbp, rsp  
4     mov     eax, DWORD PTR pi<int, 42>[rip]  
5     pop     rbp  
6     ret  
7 pi<int, 42>:  
8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

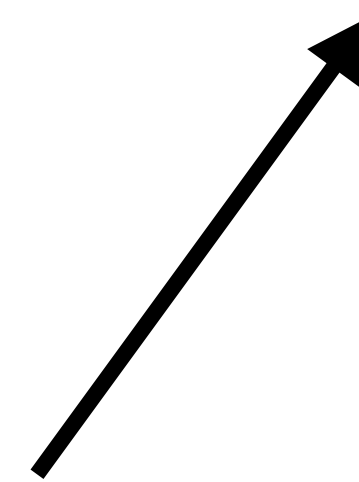
```
template<class T, int ... X>  
T pi(T(X...));
```

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

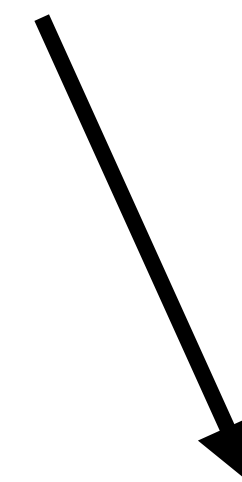


```
template<class T, int ... X>  
T pi = T(X...);
```

```
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;  
    }  
}
```


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
```

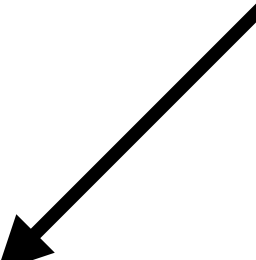
```
//foo.cpp
#include "foo.h"
void test(int y) {
    const int a = 100;

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

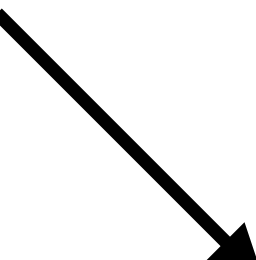
C++ difficulties: compile-time generation

```
$class interface {  
    constexpr {  
        compiler.require($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

—

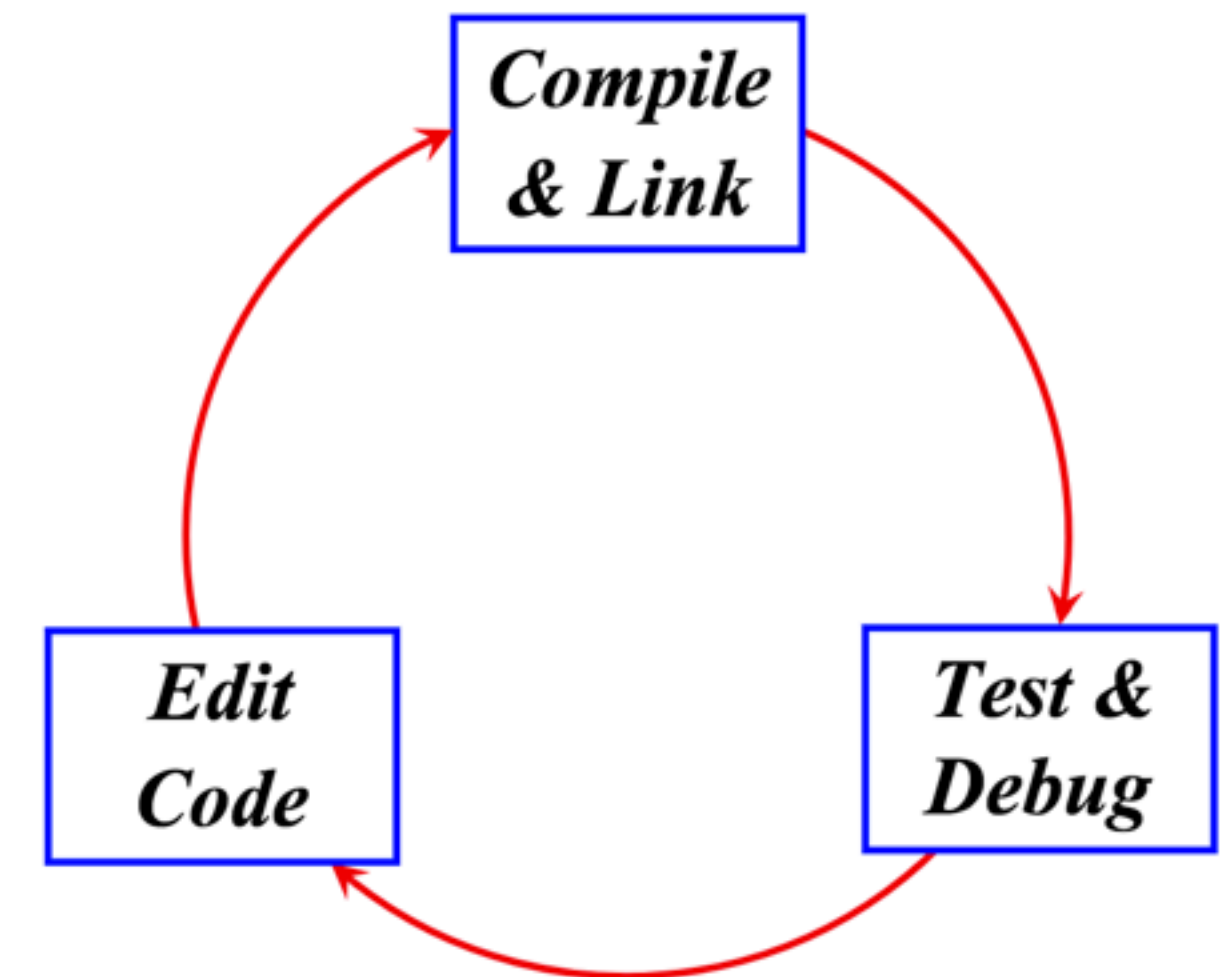
- Constexpr
- Injected code
- ...

Agenda

1. Tricky C++ language. Show samples!
2. Seems to help but it doesn't. Why?
 - Run / Debug
 - Static / dynamic code analysis
3. Should help – IDEs! How?

Do these help?

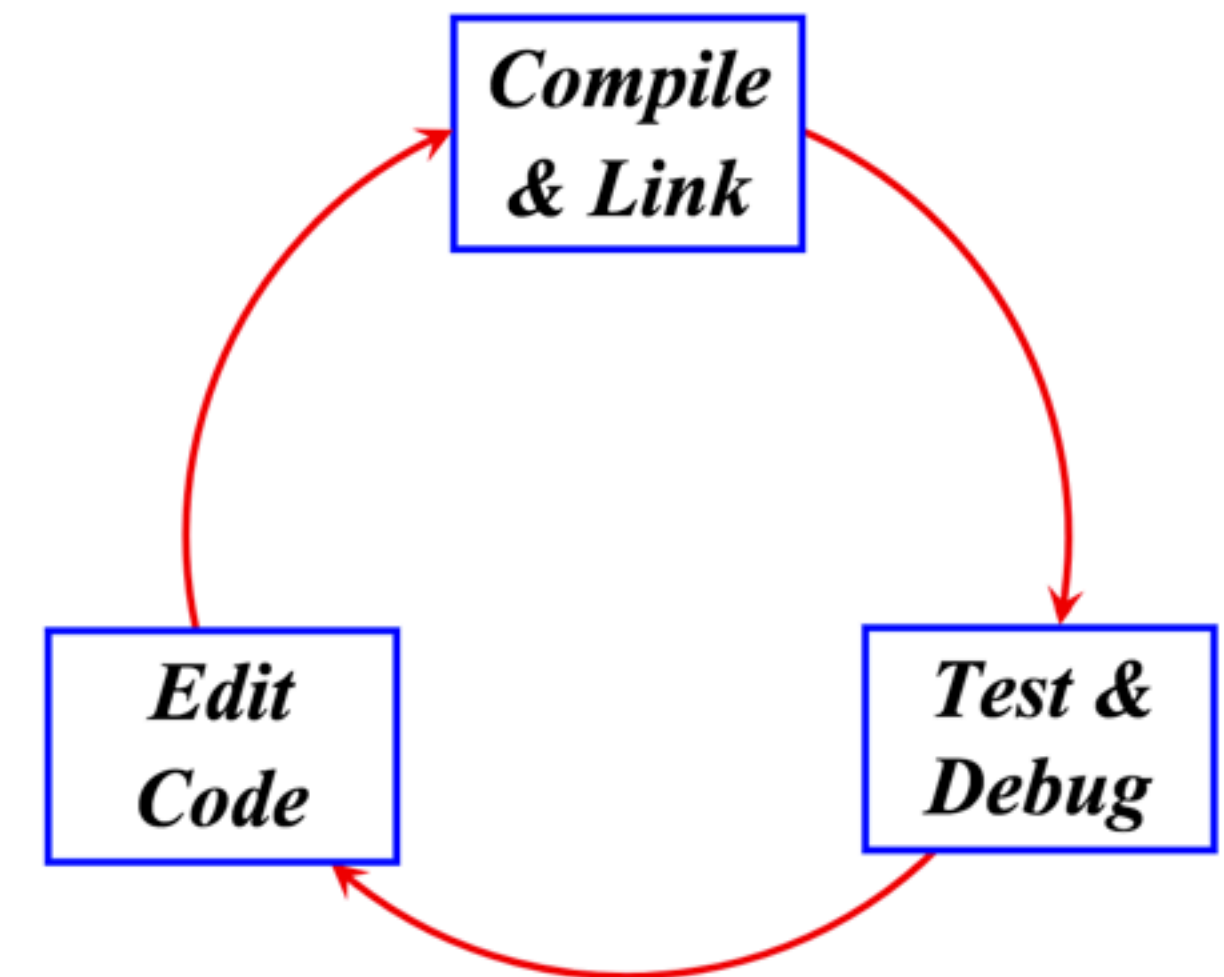
- Read-fix-run / read-fix-print-run and check results
- Debug
- Use static or dynamic code analysis



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

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The power of tools:

Macro debug

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

Existing options:

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

The power of tools: Macro debug

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)

CLAS
CLAS

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_A{public:int count_A;int call_A(){return 100;}};
```



The power of tools: Macro debug

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

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) \
};

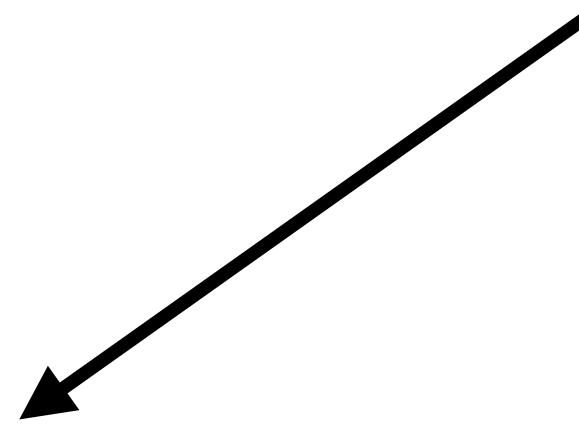
class class_A { public: int count_A; int call_A() { return 100; } };
CLASS_DEF(B)
CLASS_DEF(C)
```


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;
```



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);  
    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*

Existing options:

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

The power of tools:

Type info debug

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

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
```

Press 'F2' for focus

```
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
(local variable) double op
go to

The power of tools:

Type info debug

Substitute typedef

```
#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

Substitute typedef

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

```
MY_STRUCT(A)
```

```
MY_STRUCT(B)
```

```
MY_STRUCT(C)
```

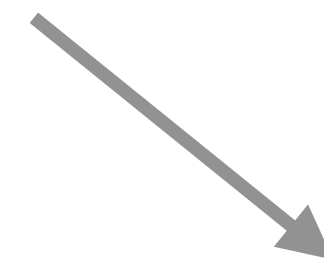
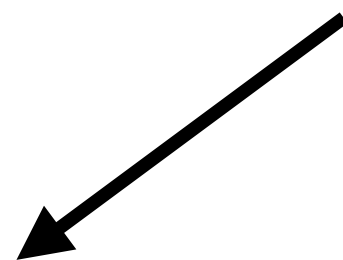
```
MY_STRUCT(D)
```

```
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
- Constexpr evaluator
- Injection evaluator

```
handle

class T1 = int
class... Types = float

template<class T1 = int, class... Types>
void handle(Tuple<T1,Types...&>)
{
    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

```
void check() {
    handle(Tuple<>());           // -> 1
    handle(Tuple<int, float>()); // -> 2
    handle(Tuple<int, float&>()); // -> 3
}

h (function) void handle<T1, Types...>(Tuple<T1, Types&...>)
  Third overload
```

The power of tools: Meta info debug

Constexpr evaluator +
Template instantiation

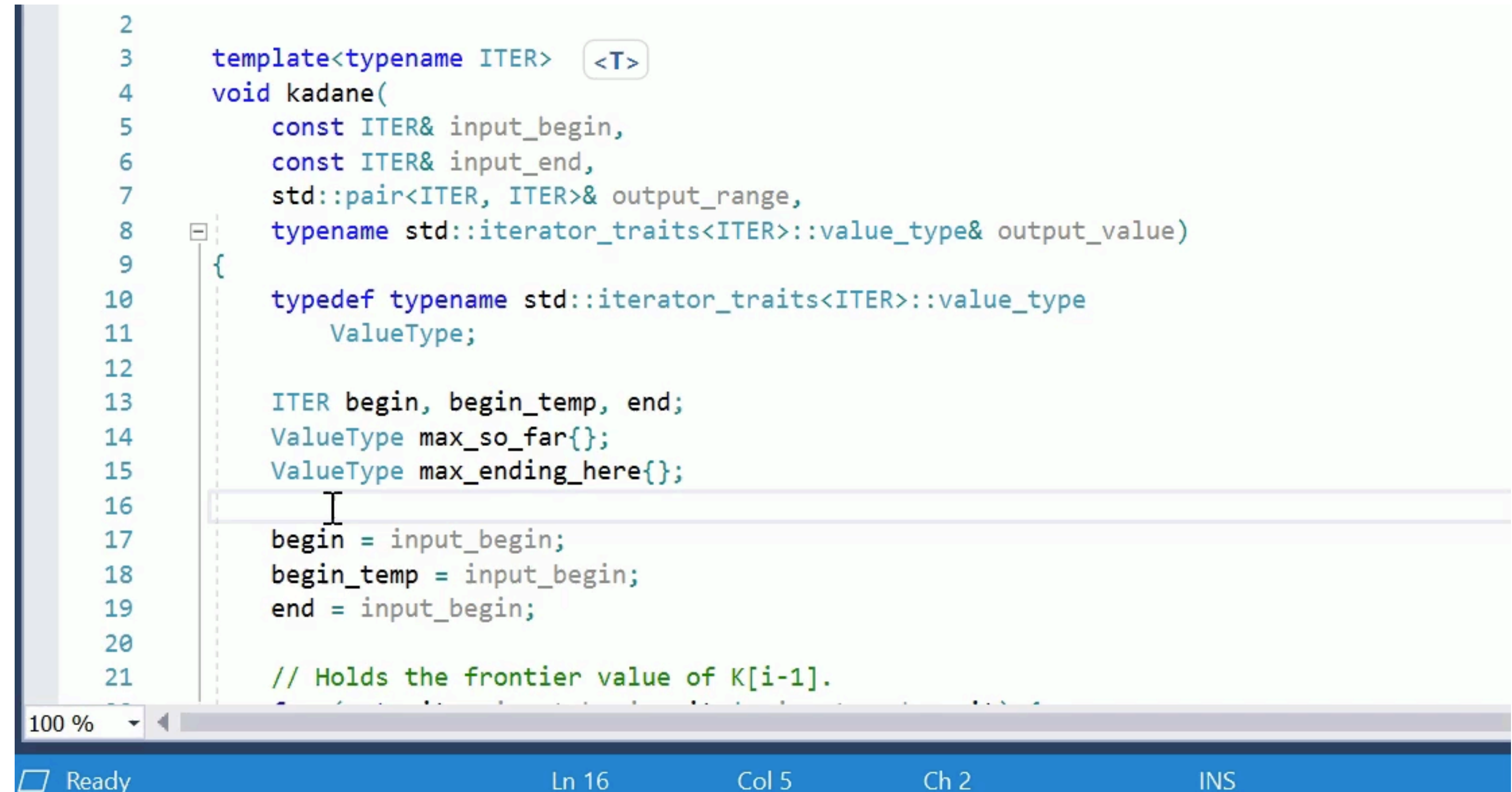
```
template <typename T>
auto get_value(T t) {
    if constexpr (std::is_pointer<T>::value)
        return *t;
    else
        return t;
}

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

Templates intellisense (#MSBuild 2018)



```
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].
```

The screenshot shows a Visual Studio code editor with a C++ file. The code is implementing Kadane's algorithm. The editor has a light blue background. The code is color-coded: keywords like 'template', 'typename', 'void', 'const', 'std', 'typedef', and 'typename' are in blue; identifiers like 'ITER', 'begin', 'begin_temp', 'end', 'max_so_far', and 'max_ending_here' are in black; and comments are in green. The line numbers 2 through 21 are visible on the left. The status bar at the bottom shows 'Ready', 'Ln 16', 'Col 5', 'Ch 2', and 'INS'. The zoom level is set to 100%.

The power of tools:

Overloads debug

Debug functions and operators overloads:

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

The power of tools: Overloads debug

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

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 – parameter info

1. One-by-one or all together
2. 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 – parameter info

1. One-by-one or all together
2. 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
```

=delete;
leToInt b) {}

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

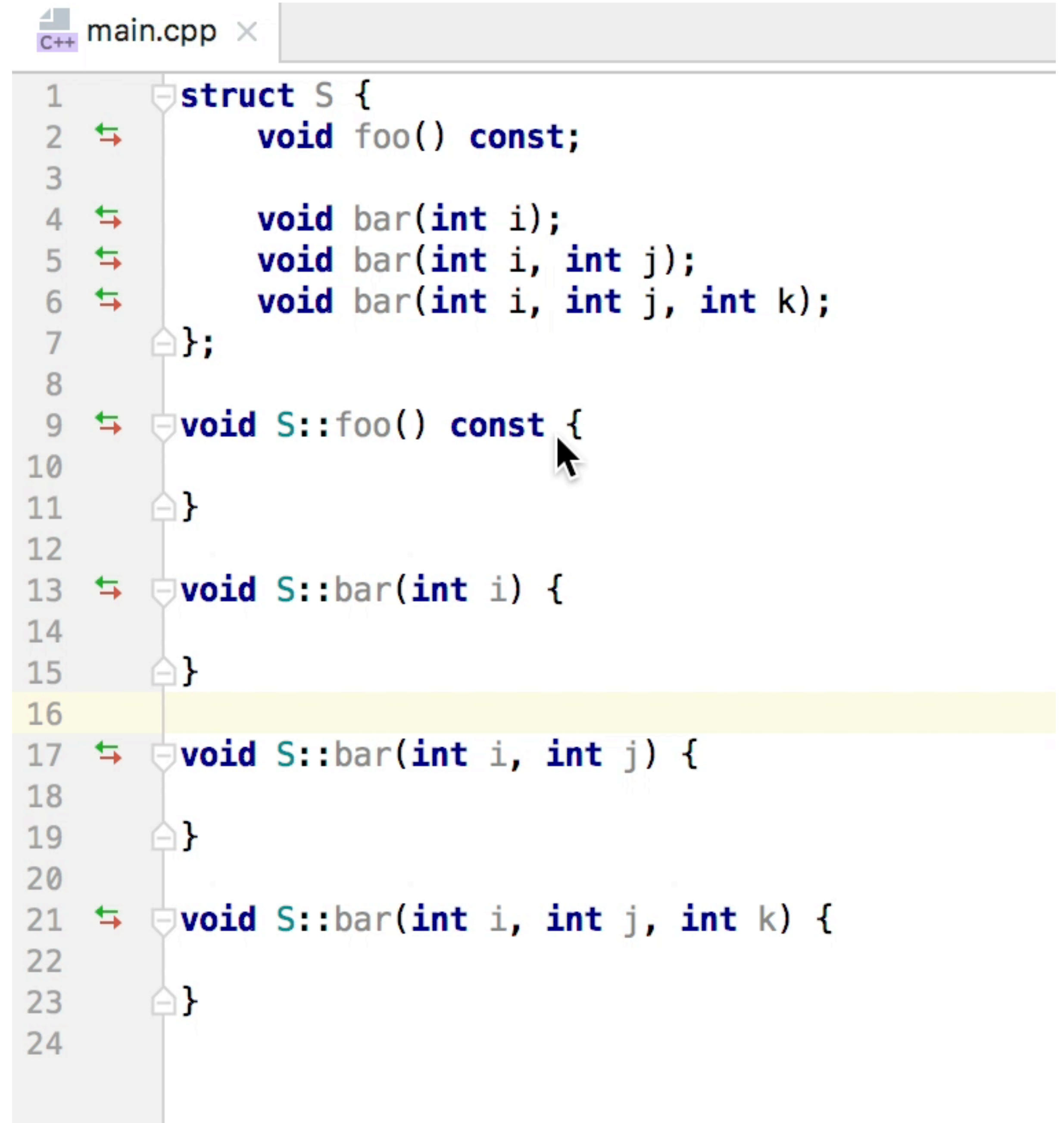
The power of tools: Overloads debug

1. Show candidates set
2. Show explanations



The power of tools: Overloads debug

1. Show candidates set
2. Show explanations
3. Navigate to similar functions/operators



```
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 void S::bar(int i, int j) {
17
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++
 - [CppCon 2017] <https://www.youtube.com/watch?v=4AfRAVcThyA>
- Niklas, bitsquid blog, Caring by Sharing: Header Hero
 - <http://bitsquid.blogspot.co.uk/2011/10/caring-by-sharing-header-hero.html>

**Thank you
for your attention**

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Questions?