Practical Performance Practices

CppCon 2016 - This session only works if you interact!

Please come forward.

Jason Turner

- http://github.com/lefticus/presentations
- http://cppcast.com
- http://chaiscript.com
- http://cppbestpractices.com
- C++ Weekly - YouTube Series
- @lefticus
- Independent Contractor
- http://articles.emptycrate.com/idocpp

I prefer an interactive session - please ask questions

Optimizing Compilers Are Amazing

```
#include <string>

int main()
{
  std::string s("a");
  return s.size();
}
```

Optimizing Compilers Are Amazing

g++ 5.1+

```
main:
        mov     eax, 1
        ret
```

Optimizing Compilers Are Amazing

```
#include <string>

int main()
{
  return std::string("a").size() + std::string("b").size();
}
```

Optimizing Compilers Are Amazing

```
.LC0:
        .string "basic_string::_M_construct null not valid"
void std::__cxx11::basic_string<char, std::char_traits<char>, std::allocator<char> >::
        push    r12
        push    rbp
        mov     r12, rsi
        push    rbx
        mov     rbp, rdi
        sub     rsp, 16
        test    rsi, rsi
        jne     .L4
        test    rdx, rdx
        je      .L4
        mov     edi, OFFSET FLAT:.LC0
        call    std::__throw_logic_error(char const*)
.L4:
        mov     rbx, rdx
        sub     rbx, r12
        cmp     rbx, 15
        mov     QWORD PTR [rsp+8], rbx
        ja      .L17
        cmp     rbx, 1
        mov     rdi, QWORD PTR [rbp+0]
        jne     .L5
        movzx   eax, BYTE PTR [r12]
        mov     BYTE PTR [rdi], al
        jmp     .L6
```

Optimizing Compilers Are Amazing

```
.L17:
        lea     rsi, [rsp+8]
        xor     edx, edx
        mov     rdi, rbp
        call    std::__cxx11::basic_string<char, std::char_traits<char>, std::allocato
        mov     rdx, QWORD PTR [rsp+8]
        mov     QWORD PTR [rbp+0], rax
        mov     rdi, rax
        mov     QWORD PTR [rbp+16], rdx
.L5:
        mov     rdx, rbx
        mov     rsi, r12
        call    memcpy
.L6:
        mov     rax, QWORD PTR [rsp+8]
        mov     rdx, QWORD PTR [rbp+0]
        mov     QWORD PTR [rbp+8], rax
        mov     BYTE PTR [rdx+rax], 0
        add     rsp, 16
        pop     rbx
        pop     rbp
        pop     r12
        ret
.LC2:
        .string "a"
.LC3:
        .string "b"
```

Optimizing Compilers Are Amazing

```
main:
        push    rbx
        mov     edx, OFFSET FLAT:.LC2+1
        mov     esi, OFFSET FLAT:.LC2
        sub     rsp, 64
        lea     rax, [rsp+16]
        mov     rdi, rsp
        mov     QWORD PTR [rsp], rax
        call    void std::__cxx11::basic_string<char, std::char_traits<char>, std::all
        lea     rax, [rsp+48]
        lea     rdi, [rsp+32]
        mov     edx, OFFSET FLAT:.LC3+1
        mov     esi, OFFSET FLAT:.LC3
        mov     rbx, QWORD PTR [rsp+8]
        mov     QWORD PTR [rsp+32], rax
        call    void std::__cxx11::basic_string<char, std::char_traits<char>, std::all
        mov     rdi, QWORD PTR [rsp+32]
        lea     rax, [rsp+48]
        add     ebx, DWORD PTR [rsp+40]
        cmp     rdi, rax
        je      .L19
        call    operator delete(void*)
.L19:
        mov     rdi, QWORD PTR [rsp]
        lea     rax, [rsp+16]
        cmp     rdi, rax
        je      .L24
        call    operator delete(void*)
```

Optimizing Compilers Are Amazing

```
.L24:
        add     rsp, 64
        mov     eax, ebx
        pop     rbx
        ret
        mov     rdi, QWORD PTR [rsp]
        lea     rdx, [rsp+16]
        mov     rbx, rax
        cmp     rdi, rdx
        je      .L22
        call    operator delete(void*)
.L22:
        mov     rdi, rbx
        call    _Unwind_Resume
```

Optimizing Compilers Are Amazing

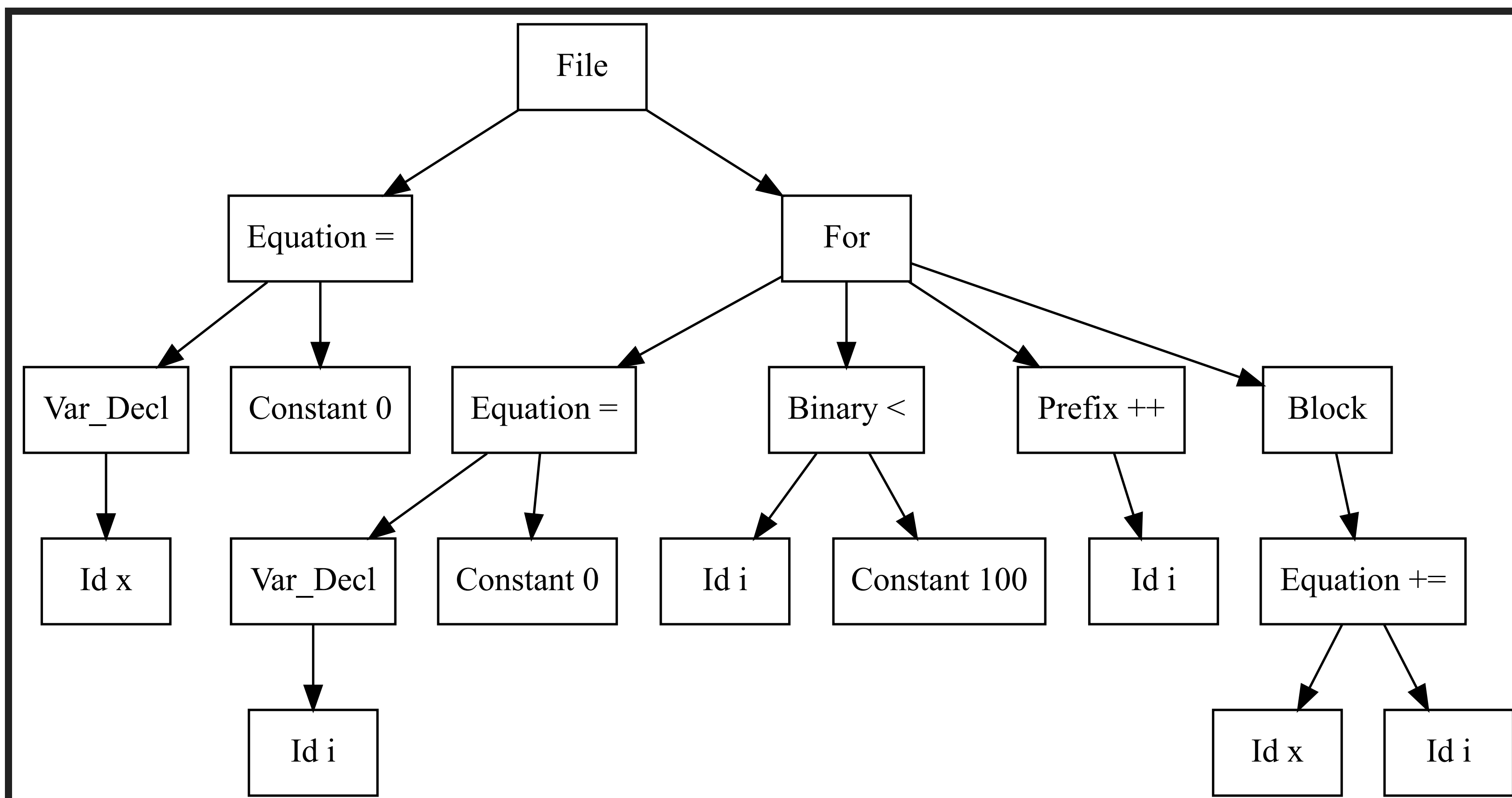
- But trying to predict what the compiler can optimize is a risky game

Profiling ChaiScript

- Performance measuring ChaiScript is difficult
- Great number of template instantations
- Nature of scripting means execution is spread over many similar functions

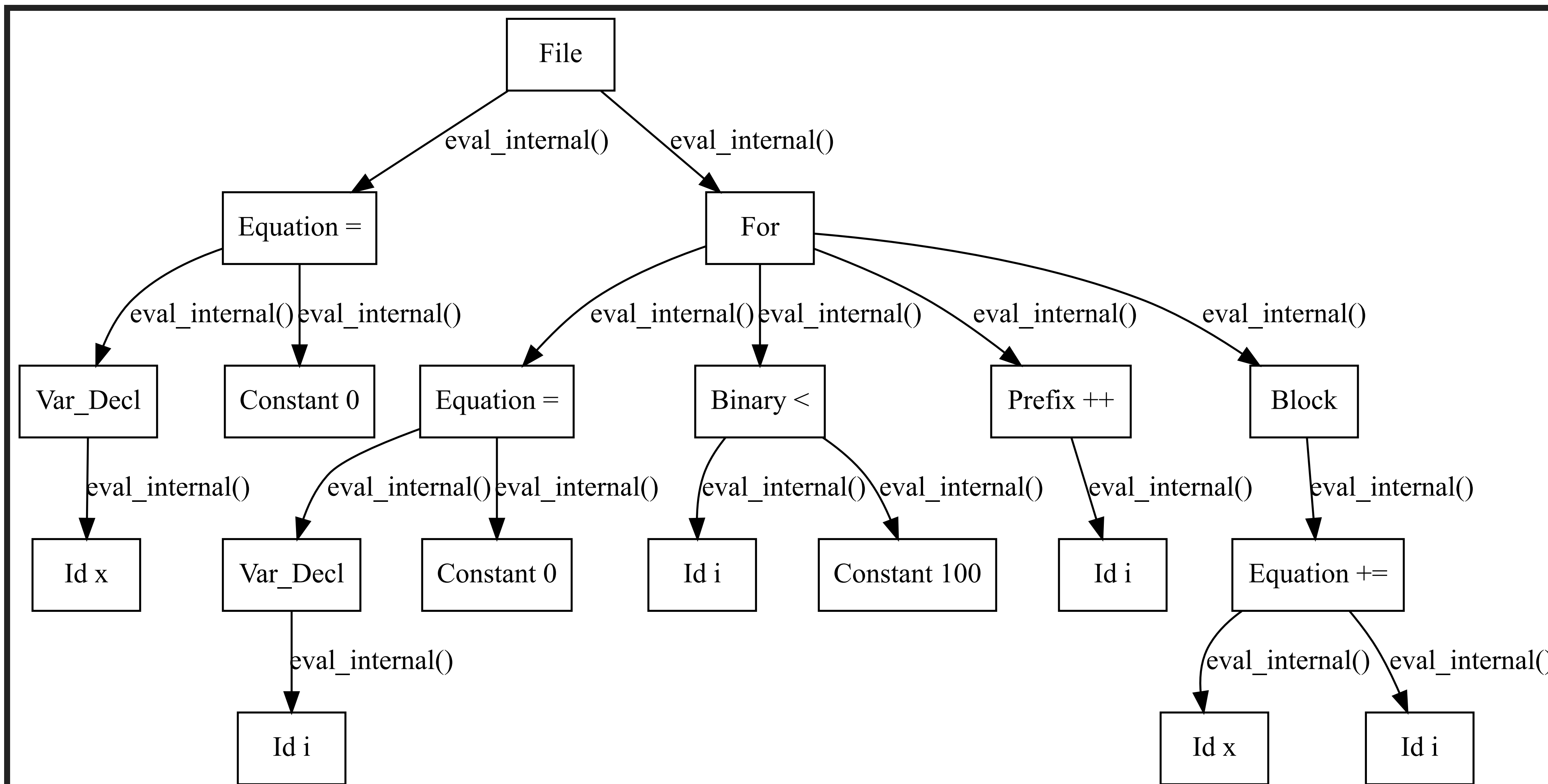
Parsed Nodes

```
var x = 0;

for (var i = 0; i < 100; ++i) {
  x += i;
}
```

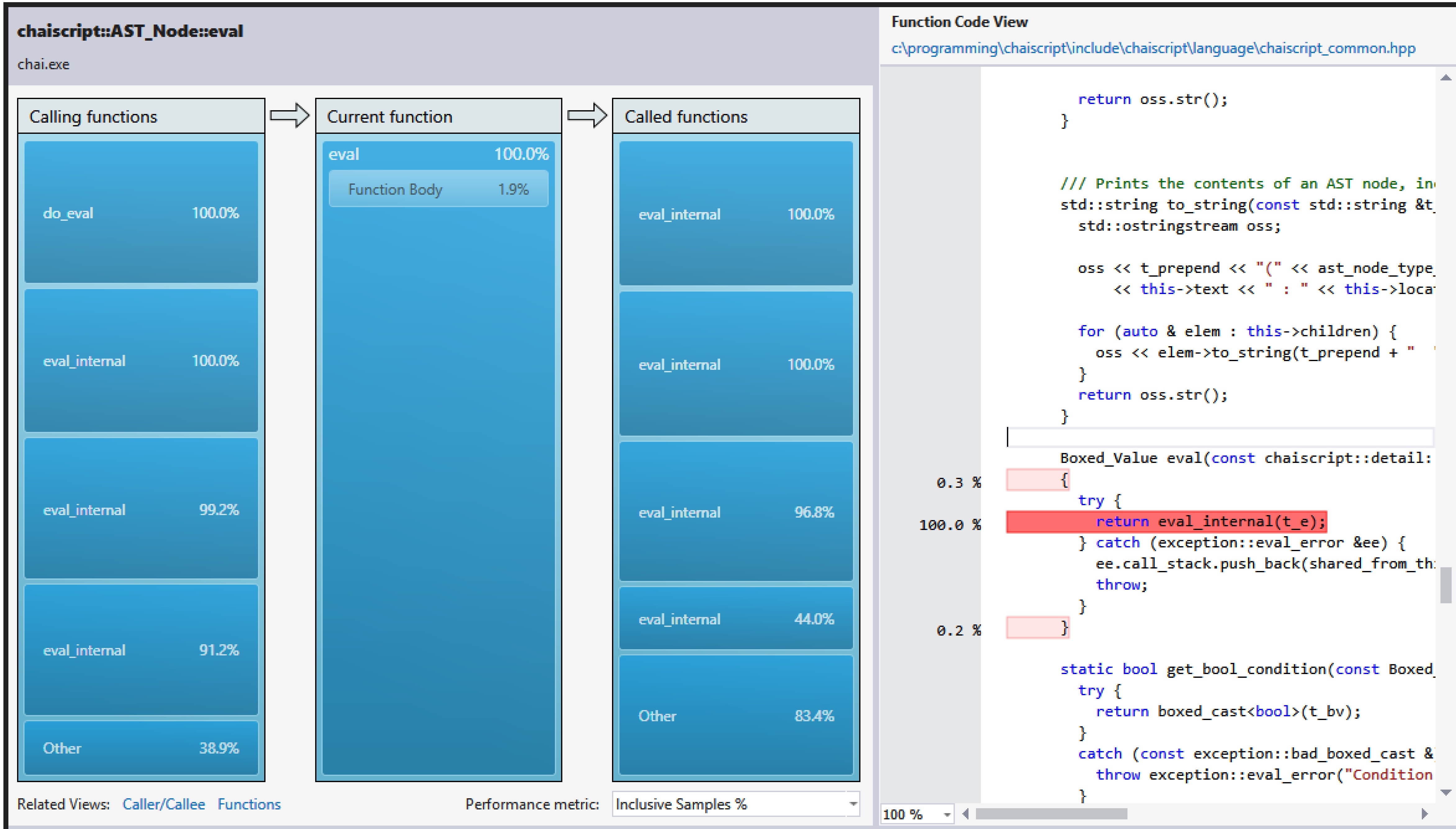


Parsed Nodes

```
var x = 0;

for (var i = 0; i < 100; ++i) {
  x += i;
}
```



Performance Profiling



Performance Practices

This led to the creation of several rules and practices that I follow to make well-performing code 'by default'

Which Is Better In Normal Use?

`std::vector`

- or -

`std::list`

- WHY?

`std::list`

`std::list`

```
int main()
{
  std::list<int> v{1};
}
```

- What has to happen here?

std::list

```
main:
        pushq   %r12
        pushq   %rbp
        movl    $24, %edi
        pushq   %rbx
        subq    $32, %rsp
        movq    $0, 16(%rsp)
        movq    %rsp, %rbp
        movq    %rsp, (%rsp)
        movq    %rsp, 8(%rsp)
        call    operator new(unsigned long)
        movq    %rax, %rdi
        movq    $0, (%rax)
        movq    $0, 8(%rax)
        movl    $1, 16(%rax)
        movq    %rsp, %rsi
        call    std::__detail::_List_node_base::_M_hook(std::__detail::_List_node_base
        movq    (%rsp), %rdi
        addq    $1, 16(%rsp)
        cmpq    %rsp, %rdi
        je      .L9
```

std::list

```
.L10:
        movq    (%rdi), %rbp
        call    operator delete(void*)
        cmpq    %rbx, %rbp
        movq    %rbp, %rdi
        jne     .L10
.L9:
        addq    $32, %rsp
        xorl    %eax, %eax
        popq    %rbx
        popq    %rbp
        popq    %r12
        ret
        movq    (%rsp), %rdi
        movq    %rax, %rbp
```

std::list

```
.L5:
        cmpq    %rbx, %rdi
        je      .L4
        movq    (%rdi), %r12
        call    operator delete(void*)
        movq    %r12, %rdi
        jmp     .L5
.L4:
        movq    %rbp, %rdi
        call    _Unwind_Resume
```

`std::list`

- Allocate a new node
- Handle exception thrown during node allocation?
- Assign the value
- Hook up some pointers
- Delete node
- etc?

`std::vector`

std::vector

```
int main()
{
  std::vector<int> v{1};
}
```

- What has to happen here?

std::vector

```
main:
        subq    $8, %rsp
        movl    $4, %edi
        call    operator new(unsigned long)
        movl    $1, (%rax)
        movq    %rax, %rdi
        call    operator delete(void*)
        xorl    %eax, %eax
        addq    $8, %rsp
        ret
```

- Allocate a buffer
- Assign a value in the buffer
- Delete the buffer

Part 1: Don't Do More Work Than You Have To

Don't Do More Work Than You Have To

What about `std::array`?

```
int main()
{
  std::array<int, 1> v{1};
}
```

Don't Do More Work Than You Have To

What about `std::array`?

```
int main()
{
  std::array<int, 1> v{1};
}
```

```
main:
        xorl    %eax, %eax
        ret
```

- Code is completely compiled away

Don't Do More Work Than You Have To

Container Practices

- Always prefer `std::array`
- Then `std::vector`
- Then only differ if you need specific behavior
- Make sure you understand what the library has to do

Don't Do More Work Than You Have To

```
int main()
{
  std::string s;
  s = "A Somewhat Rather Long String";
}
```

- Construct a string object
- Reassign string object

Don't Do More Work Than You Have To

Always `const`

```
int main()
{
  const std::string s = "A Somewhat Rather Long String";
}
```

- Construct and initialize in one step
- ~32% more efficient

Don't Do More Work Than You Have To

Always `const` - Complex Initialization

```
int main()
{
  const int i = std::rand();
  std::string s;
  switch (i % 4) {
    case 0:
      s = "long string is mod 0";
      break;
    case 1:
      s = "long string is mod 1";
      break;
    case 2:
      s = "long string is mod 2";
      break;
    case 3:
      s = "long string is mod 3";
      break;
  }
}
```

- How can we make `s` `const` in this context?

Don't Do More Work Than You Have To

Always `const` - Complex Initialization - *Use IIFE*

```cpp
int main()
{
  const int i = std::rand();
  const std::string s = [&](){
    switch (i % 4) {
      case 0:
        return "long string is mod 0";
      case 1:
        return "long string is mod 1";
      case 2:
        return "long string is mod 2";
      case 3:
        return "long string is mod 3";
    }
  }();
}
```

- ~31% more efficient

Don't Do More Work Than You Have To

Always Initialize When Const Isn't Practical

```
struct Int
{
  Int(std::string t_s)
  {
    m_s = t_s;
  }

  int val() const {
    return std::atoi(m_s.c_str());
  }

  std::string m_s;
};
```

- Same issues as previous examples

Don't Do More Work Than You Have To

Always Initialize When Const Isn't Practical

```
struct Int
{
  Int(std::string t_s) : m_s(std::move(t_s))
  {
  }

  int val() const {
    return std::atoi(m_s.c_str());
  }

  std::string m_s;
};
```

- Same gains as const initializer
- What's wrong with this version now?
- val() parses string on each call

Don't Do More Work Than You Have To

Don't Recalculate Values - Calculate on First Use

```
struct Int
{
  Int(std::string t_s) : s(std::move(t_s))
  { }

  int val() const {
    if (!is_calculated) {
      value = std::atoi(s);
    }
    return value;
  }

  mutable bool is_calculated = false;
  mutable int value;
  std::string s;
};
```

- What's wrong now?
- C++ Core Guidelines state that const methods should be thread safe
- What else?
- `is_calculated` isn't being set

Don't Do More Work Than You Have To

Don't Recalculate Values - Calculate On First Use

```
struct Int
{
  Int(std::string t_s) : s(std::move(t_s))
  { }

  int val() const {
    if (!is_calculated) {
      value = std::atoi(s);
      is_calculated = true;
    }
    return value;
  }

  mutable std::atomic_bool is_calculated = false;
  mutable std::atomic_int value;
  std::string s;
};
```

- Branching is slower
- Atomics are slower

Don't Do More Work Than You Have To

Don't Recalculate Values - Calculate At Construction

```
struct Int
{
  Int(const std::string &t_s) : m_i(std::atoi(t_s.c_str()))
  { }

  int val() const {
    return m_i;
  }

  int m_i;
};
```

- No branching, no atomics, smaller runtime (int vs string)
- In the context of a large code base, this took ~2 years to find
- Resulted in 10% performance improvement across system
- *The simpler solution is almost always the best solution*

Don't Do More Work Than You Have To

Initialization Practices

- Always const
- Always initialize
- Using IIFE can help you initialize
- Don't recalculate values that can be calculated once

Don't Do More Work Than You Have To

```
struct Base {
  virtual ~Base() = default;
  virtual void do_a_thing() = 0;
};

struct Derived : Base {
  virtual ~Derived() = default;
  void do_a_thing() override {}
};
```

- What's wrong here?
- move construction / assignment is disabled (virtual destructor)
- `virtual ~Derived()` is unnecessary

Don't Do More Work Than You Have To

Don't Disable Move Operations / Use Rule of 0

```
struct Base {
  virtual ~Base() = default;
  Base() = default;
  Base(const Base &) = default; Base& operator=(const Base&) = default;
  Base(Base &&) = default; Base& operator=(Base &&) = default;

  virtual void do_a_thing() = 0;
};

struct Derived : Base {
  virtual void do_a_thing() {}
};
```

- 10% improvement with fixing this in just one commonly used class

Don't Do More Work Than You Have To

On The Topic Of Copying

```
#include <string>

struct S {
  S(std::string t_s) : s(std::move(t_s)) {}
  std::string s;
};

int main()
{
  for (int i = 0; i < 10000000; ++i) {
    std::string s = std::string("a not very short string") + "b";
    S o(s);
  }
}
```

- We all know that copying objects is bad
- So let's use `std::move`

Don't Do More Work Than You Have To

On The Topic Of Copying

```
#include <string>

struct S {
  S(std::string t_s) : s(std::move(t_s)) {}
  std::string s;
};

int main()
{
  for (int i = 0; i < 10000000; ++i) {
    std::string s = std::string("a not very short string") + "b";
    S o(std::move(s));
  }
}
```

- 29% more efficient
- 32% smaller binary
- Good! But what's better?

Don't Do More Work Than You Have To

Avoid Named Temporaries

```
#include <string>

struct S {
  S(std::string t_s) : s(std::move(t_s)) {}
  std::string s;
};

int main()
{
  for (int i = 0; i < 10000000; ++i) {
    S o(std::string("a not very short string") + "b");
  }
}
```

- 2% more efficient again
- Can lead to less readable code sometimes, but more maintainable than `std::move` calls
- This is taking the "don't declare a variable until you need it" philosophy to its ultimate conclusion

Don't Do More Work Than You Have To

```
int use_a_base(std::shared_ptr<Base> p)
{
  return p->value();
}

int main()
{
  auto ptr = std::make_shared<Derived>();
  use_a_base(ptr);
}
```

- What's the problem here?
- Copies are being made of `shared_ptr<Base>`

Don't Do More Work Than You Have To

Avoid (shared_ptr) Copies

```
int use_a_base(const std::shared_ptr<Base> &p)
{
  return p->value();
}

int main()
{
  auto ptr = std::make_shared<Derived>();
  use_a_base(ptr);
}
```

- Fixed!
- Right?
- Wrong!

Don't Do More Work Than You Have To

Avoid Automatic Conversions

```
int use_a_base(const Base &p)
{
  return p->value();
}

int main()
{
  auto ptr = std::make_shared<Derived>();
  use_a_base(ptr.get());
}
```

- This version is 2.5x faster than the last

Don't Do More Work Than You Have To

`std::endl`

```
void println(ostream &os, const std::string &str)
{
  os << str << std::endl;
}
```

- What does `std::endl` do?
- it's equivalent to `'\n' << std::flush`
- Expect that flush to cost you at least 9x overhead in your IO

Don't Do More Work Than You Have To

Real World `std::endl` Anecdote

```
void write_file(std::ostream &os) {
  os << "a line of text" << std::endl;
  os << "another line of text" << std::endl;
  /* snip */
  os << "many more lines of text" << std::endl;
}

void write_file(const std::string &filename) {
  std::ofstream ofs(filename.c_str());
  write_file(ofs);
}

std::string get_file_as_string() {
  std::stringstream ss;
  write_file(ss);
  return ss.str();
}
```

Don't Do More Work Than You Have To

Avoid `std::endl`

Prefer just using `'\n'`

```
void println(ostream &os, const std::string &str)
{
  os << str << '\n';
}
```

Don't Do More Work Than You Have To

Hidden Work Practices

- Calculate values once - at initialization time
- Obey the rule of 0
- If it looks simpler, it's probably faster
- Avoid object copying
- Avoid automatic conversions
  - Don't pass smart pointers
  - Make conversion operations explicit
- Avoid `std::endl`

Don't Do More Work Than You Have To

`shared_ptr` Instantiations

Don't Do More Work Than You Have To

`shared_ptr` Instantiations

```
int main() {
  std::make_shared<int>(1);
}
```

Don't Do More Work Than You Have To

`shared_ptr` Instantiations

```
std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__gnu_cxx::_Lock_policy)2>::~_
        rep ret
std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__gnu_cxx::_Lock_policy)2>::_M
        rep ret
std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__gnu_cxx::_Lock_policy)2>::_M
        movq    8(%rsi), %rsi
        movq    %rdi, %rdx
        cmpq    typeinfo name for std::_Sp_make_shared_tag, %rsi
        je      .L4
        xorl    %eax, %eax
        cmpb    $42, (%rsi)
        je      .L3
        movl    typeinfo name for std::_Sp_make_shared_tag, %edi
        movl    $24, %ecx
        repz cmpsb
        jne     .L3
.L4:
        leaq    16(%rdx), %rax
```

Don't Do More Work Than You Have To

`shared_ptr` Instantiations

```
.L3:
        rep ret
std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__gnu_cxx::_Lock_policy)2>::~_
        movl    $24, %esi
        jmp     operator delete(void*, unsigned long)
std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__gnu_cxx::_Lock_policy)2>::_M
        jmp     operator delete(void*)
main:
        pushq   %rbx
        movl    $24, %edi
        call    operator new(unsigned long)
        movq    %rax, %rbx
        movl    $1, 8(%rax)
        movl    $1, 12(%rax)
        movq    vtable for std::_Sp_counted_ptr_inplace<int, std::allocator<int>, (__g
        movl    $0, 16(%rax)
        movl    __gthrw___pthread_key_create(unsigned int*, void (*)(void*)), %eax
        testq   %rax, %rax
        je      .L17
        leaq    8(%rbx), %rdi
        orl     $-1, %esi
        call    __gnu_cxx::__exchange_and_add(int volatile*, int)
        subl    $1, %eax
        je      .L26
```

Don't Do More Work Than You Have To

`shared_ptr` Instantiations

```
.L22:
        xorl    %eax, %eax
        popq    %rbx
        ret
.L17:
        movl    $0, 8(%rbx)
        movl    $0, 12(%rbx)
.L23:
        movq    (%rbx), %rax
        movq    %rbx, %rdi
        movq    24(%rax), %rax
        call    *%rax
        jmp     .L22
.L26:
        movq    (%rbx), %rax
        movq    %rbx, %rdi
        movq    16(%rax), %rax
        call    *%rax
        leaq    12(%rbx), %rdi
        orl     $-1, %esi
        call    __gnu_cxx::__exchange_and_add(int volatile*, int)
        subl    $1, %eax
        jne     .L22
        jmp     .L23
```

Don't Do More Work Than You Have To

`unique_ptr` Instantiations

Don't Do More Work Than You Have To

`unique_ptr` Instantiations

```
int main()
{
  std::make_unique<int>(0);
}
```

- What does this have to do?

Don't Do More Work Than You Have To

`unique_ptr` Instantiations

```
int main()
{
  std::make_unique<int>(0);
}
```

```
main:
        sub     rsp, 8
        mov     edi, 4
        call    operator new(unsigned long)
        mov     esi, 4
        mov     DWORD PTR [rax], 0
        mov     rdi, rax
        call    operator delete(void*, unsigned long)
        xor     eax, eax
        add     rsp, 8
        ret
```

Don't Do More Work Than You Have To

`unique_ptr` Compared To Manual Memory Management

```
int main()
{
  auto i = new int(0);
  delete i;
}
```

```
main:
        sub     rsp, 8
        mov     edi, 4
        call    operator new(unsigned long)
        mov     esi, 4
        mov     DWORD PTR [rax], 0
        mov     rdi, rax
        call    operator delete(void*, unsigned long)
        xor     eax, eax
        add     rsp, 8
        ret
```

Identical

Part 1: Don't Do More Work Than You Have To - Summary

- Avoid `shared_ptr`
- Avoid `std::endl`
- Always `const`
- Always initialize with meaningful values
- Don't recalculate immutable results

Part 1: Questions?

Part 2: Smaller Code Is Faster Code

Smaller Code Is Faster Code

```
struct B
{
  virtual ~B() = default; // plus the other default operations
  virtual std::vector<int> get_vec() const = 0;
};

template<typename T>
struct D : B
{
  std::vector<int> get_vec() const override { return m_v; }
  std::vector<int> m_v;
}
```

- With many template instantiations this code blows up in size quickly

Smaller Code Is Faster Code

DRY In Templates

```
struct B
{
  virtual ~B() = default; // plus the other default operations
  virtual std::vector<int> get_vec() const { return m_v; }
  std::vector<int> m_v;
};

template<typename T>
struct D : B
{
}
```

Smaller Code Is Faster Code

Factories

Smaller Code Is Faster Code

Factories

```
struct B {
  virtual ~B() = default;
};

template<int T>
struct D : B {
};

template<int T>
std::shared_ptr<B> d_factory() {
  return std::make_shared<D<T>>();
}

int main() {
  std::vector<std::shared_ptr<B>> v{
    d_factory<1>(), d_factory<2>(), /* ... */ , d_factory<29>(), d_factory<30>()
  };
}
```

- Prefer returning `unique_ptr<>` (Back To The Basics - Herb Sutter ~0:19)
- We already saw that `shared_ptr<>` is big - don't make more than you have to

Smaller Code Is Faster Code

Prefer return `unique_ptr<>` *from factories*

```
struct B {
  virtual ~B() = default;
};

template<int T>
struct D : B {
};

template<int T>
std::unique_ptr<B> d_factory() {
  return std::make_unique<D<T>>();
}

int main() {
  std::vector<std::shared_ptr<B>> v{
    d_factory<1>(), d_factory<2>(), /* ... */ , d_factory<29>(), d_factory<30>()
  };
}
```

Smaller Code Is Faster Code

Prefer return `unique_ptr<>` *from factories*

```
template<int T> std::unique_ptr<B> d_factory()
{
  return std::make_unique<D<T>>();
}
```

1.30s compile, 30k exe, 149796k compile RAM

```
template<int T> std::shared_ptr<B> d_factory()
{
  return std::make_shared<D<T>>();
}
```

2.24s compile, 70k exe, 164808k compile RAM

```
template<int T> std::shared_ptr<B> d_factory()
{
  return std::make_unique<D<T>>();
}
```

2.43s compile, 91k exe, 190044k compile RAM

Smaller Code Is Faster Code

Prefer return `unique_ptr<>` *from factories* - ChaiScript Numbers

```
std::unique_ptr<B> d_factory()
{
  return std::make_unique<D>();
}
```

4925k exe

```
std::shared_ptr<B> d_factory()
{
  return std::make_shared<D>();
}
```

7350k exe, ~6% slower

```
std::shared_ptr<B> d_factory()
{
  return std::make_unique<D>();
}
```

7573k exe, ~10% slower (very surprising when I found this bottleneck)

Smaller Code Is Faster Code

Prefer return `unique_ptr<>` from factories - A Note About Performance

```
template<int T> std::shared_ptr<B> d_factory()
{
  return std::make_shared<D<T>>();
}
```

- This `make_shared` version is faster in raw performance
- If you create many short-lived shared objects, the `make_shared` version is fastest
- If you create long-lived shared objects, use the `make_unique` version is fastest
- C++ Core Guidelines are surprisingly inconsistent in examples for factories

Smaller Code Is Faster Code

```
std::string add(const std::string &lhs, const std::string &rhs) {
  return lhs + rhs;
}

int main() {
  const std::function<std::string (const std::string &)> f
    = std::bind(add, "Hello ", std::placeholders::_1);
  f("World");
}
```

Smaller Code Is Faster Code

Avoid `std::function<>`

```
std::string add(const std::string &lhs, const std::string &rhs) {
  return lhs + rhs;
}

int main() {
  const std::function<std::string (const std::string &)> f
    = std::bind(add, "Hello ", std::placeholders::_1);
  f("World");
}
```

- 2.9x slower than bare function call
- 30% compile time overhead
- ~10% compile size overhead

Smaller Code Is Faster Code

Never. Ever. Ever. Use `std::bind`

```
std::string add(const std::string &lhs, const std::string &rhs) {
  return lhs + rhs;
}

int main() {
  const auto f = std::bind(add, "Hello ", std::placeholders::_1);
  f("World");
}
```

- 1.9x slower than bare function call
- ~15% compile time overhead
- Effective Modern C++ #34
- Any talk on `std::function` from STL

Smaller Code Is Faster Code

Use Lambdas

```
std::string add(const std::string &lhs, const std::string &rhs) {
  return lhs + rhs;
}

int main() {
  const auto f = [](const std::string &b) {
    return add("Hello ", b);
  };
  f("World");
}
```

- 0 overhead compared to direct function call
- 0% compile time overhead

Part 2: Smaller Code Is Faster Code - Summary

- Don't repeat yourself in templates
- Avoid use of `shared_ptr`
- Avoid `std::function`
- Never use `std::bind`

Part 2: Smaller Code Is Faster Code - Questions

Bonus Slide - Avoid Non-Local Data

Non-Locals Tend To

1. Be statics - which have a cost associated
2. Need some kind of mutex protection
3. Be in a container with on-trivial lookup costs (`std::map<>` for example)

Summary

- First ask yourself: What am I asking the compiler to do here?

Initialization Practices

- Always const
- Always initialize

Hidden Work Practices

- Calculate values once - at initialization time
- Obey the rule of 0
- If it looks simpler, it's probably faster
- Avoid automatic conversions - use `explicit`
- avoid `std::endl`

Summary (Continued)

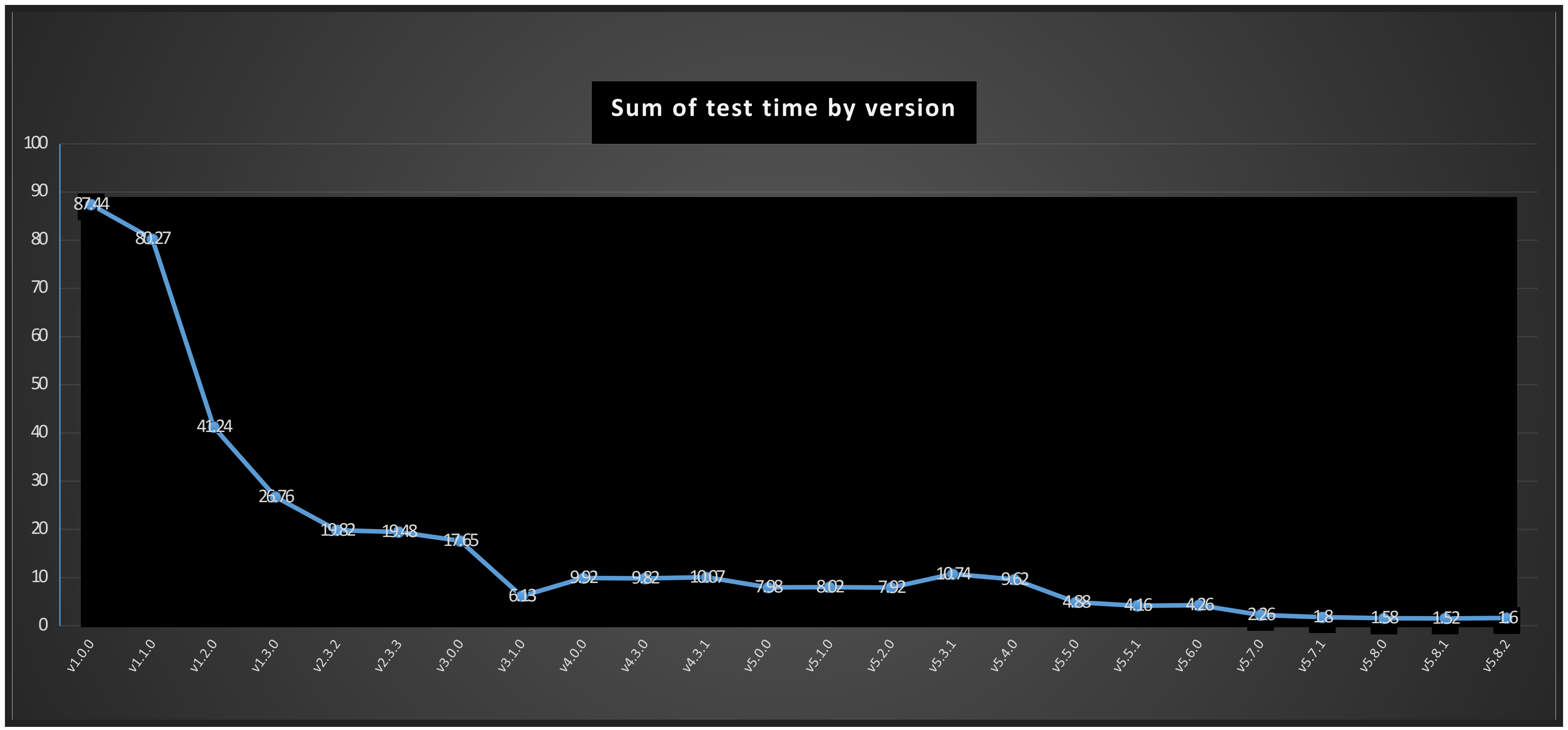
Container Practices

- Always prefer `std::array`
- Then `std::vector`
- Then only differ if you need specific behavior
- Make sure you understand what the library has to do

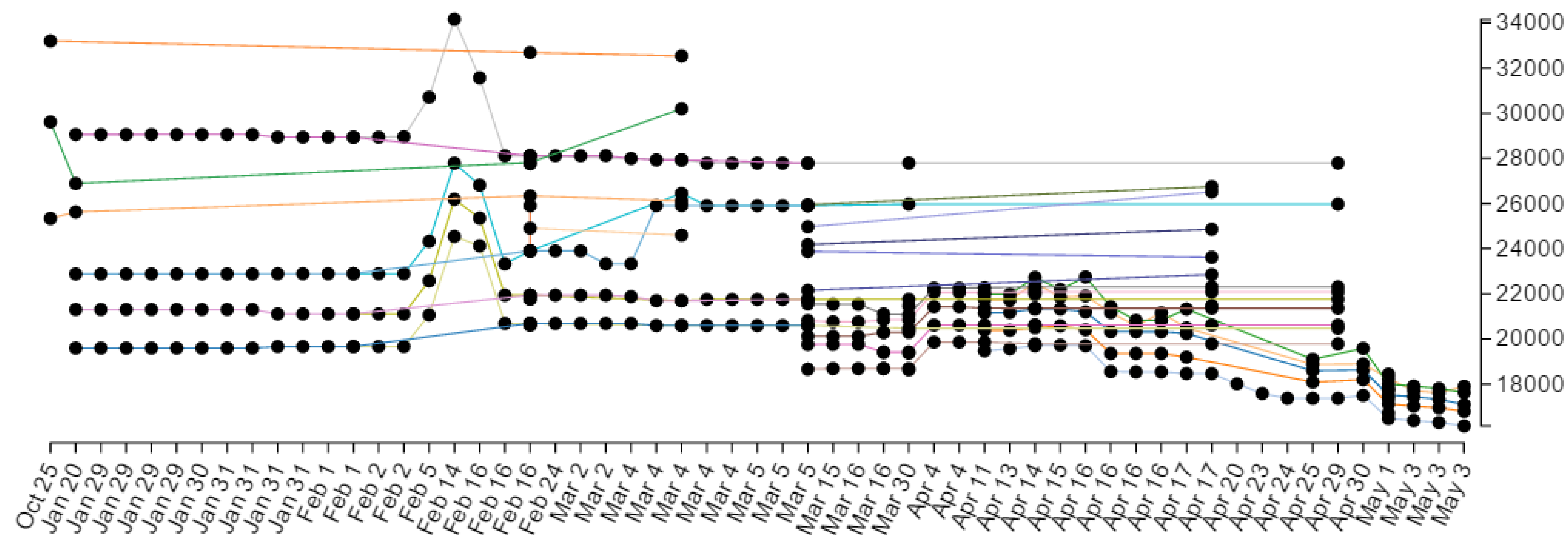
Smaller Code Is Faster Code Practices

- Don't repeat yourself in templates
- Avoid use of `std::shared_ptr`
- Avoid `std::function`
- Never use `std::bind`

Performance History



Performance Monitoring



What About `constexpr`?

What About constexpr?

```
template<typename Itr>
constexpr bool is_sorted(Itr begin, const Itr &end)
{
  Itr start = begin;
  ++begin;
  while (begin != end) {
    if (!(*start < *begin)) { return false; }
    start = begin;
    ++begin;
  }
  return true;
}

template<typename T>
constexpr bool is_sorted(const std::initializer_list<T> &l) {
  return is_sorted(l.begin(), l.end());
}

int main()
{
  return is_sorted({1,2,3,4,5});
}
```

What About constexpr?

```
main:                                   # @main
        mov     eax, 1
        ret
```

What About *Not* `constexpr`?

```
template<typename Itr>
bool is_sorted(Itr begin, const Itr &end)
{
  Itr start = begin;
  ++begin;
  while (begin != end) {
    if (!(*start < *begin)) { return false; }
    start = begin;
    ++begin;
  }
  return true;
}

template<typename T>
bool is_sorted(const std::initializer_list<T> &l) {
  return is_sorted(l.begin(), l.end());
}

int main()
{
  return is_sorted({1,2,3,4,5});
}
```

- What does this compile to?

What About *Not* constexpr? (with optimizations enabled)

```
main:                                   # @main
        mov     eax, 1
        ret
```

`constexpr`

- Full `constexpr` enabling of every data structure that can be can result in bigger code
- Bigger code is often slower code
- If you enable `constexpr` make sure you go all the way

A Quick Note On `final`

- Proper use of `final` can help the compiler optimize virtual function calls.
- If you know that a class or method will be the `final` version, mark it as such

So Why Does This All Work?

So Why Does This All Work?

Branches and Predictions

- Code branches are expensive
- Simpler code has fewer branches
- (Acccording to oprofile) ChaiScript v5.8.3 has 1.86x fewer branches then v5.1.0, and 3x the branch prediction success rate

So Why Does This All Work?

Cache Hits

- CPU cache is many (hundreds of) times faster than main memory
- Smaller code (and simpler code is smaller) is more likely to fit in to the CPU cache
- (According to oprofile) ChaiScript v5.8.3 hits the Last Level Cache 35x less often than v5.1.0, and has 1% better cache hits rates when it does

So Why Does This All Work?

Doing What The Compiler Author Expects

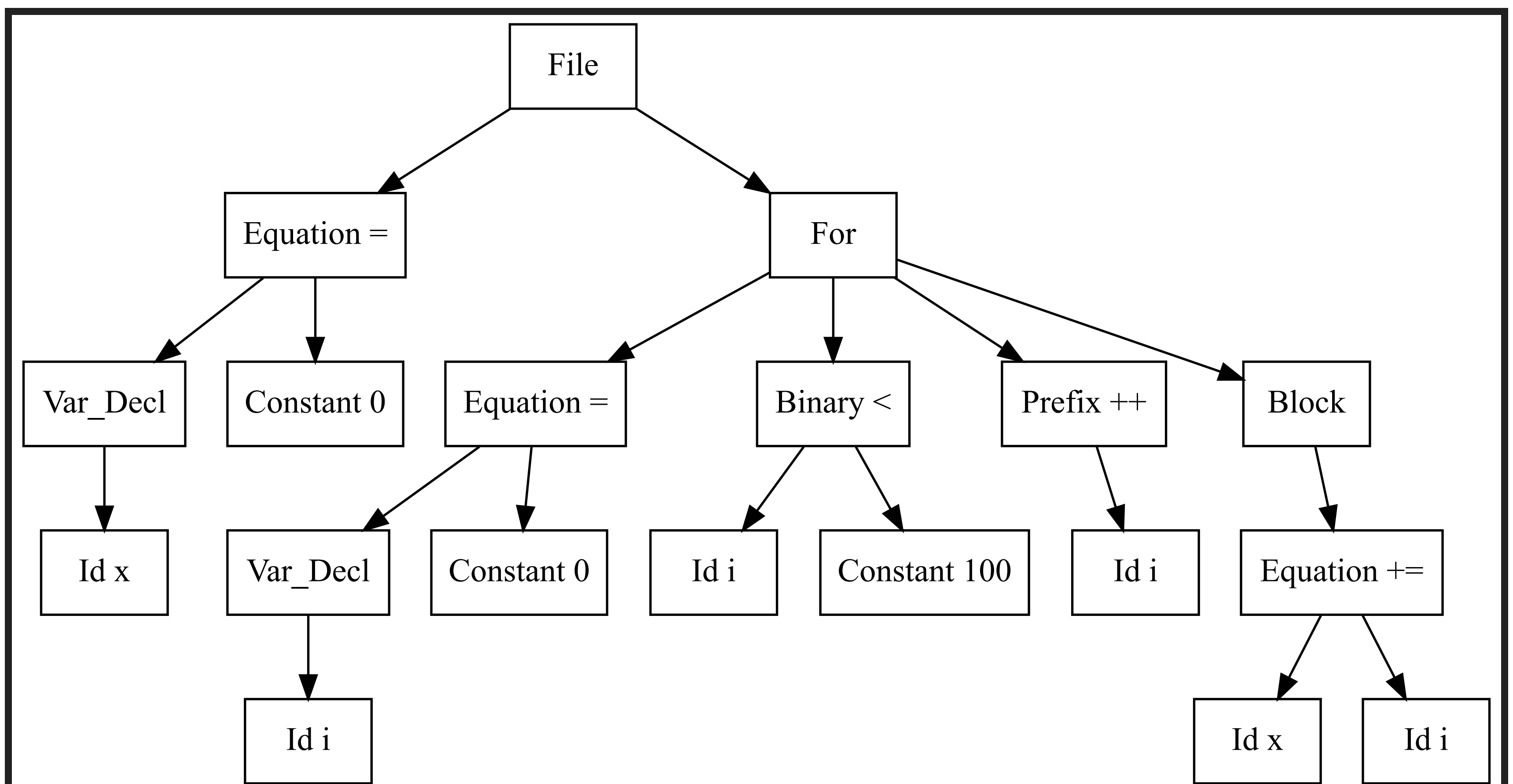
- Idiomatic C++ falls into certain patterns that compiler authors expect to find
- Well known patterns can be optimized better

What's Next?

What's Next?

Simplifying User Input - Before

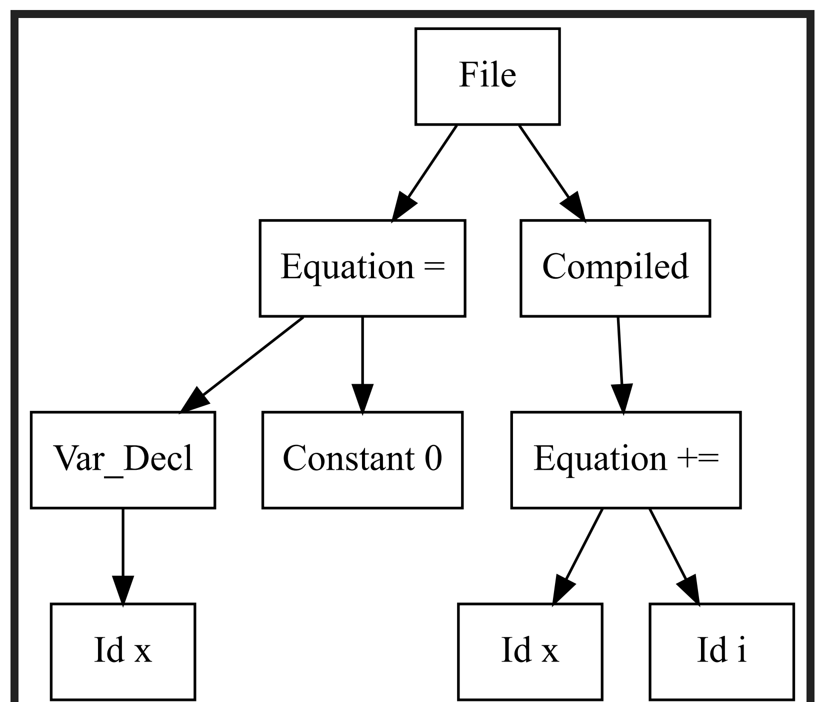
```
var x = 0;

for (var i = 0; i < 100; ++i) {
  x += i;
}
```



What's Next?

Simplifying User Input - After

```
var x = 0;

for (var i = 0; i < 100; ++i) {
  x += i;
}
```



What's Next?

Simplifying User Input

Nearly every project of significance relies on user input.

Are there ways you can simplify your user input to make the execution of your program faster?

Questions?

Jason Turner

- http://github.com/lefticus/presentations
- http://cppcast.com
- http://chaiscript.com
- http://cppbestpractices.com
- C++ Weekly - YouTube
- @lefticus
- Independent Contractor
- http://articles.emptycrate.com/idocpp
- Coupons!