Debugging of optimized code:
Extending the lifetime of local variables and parameters

Wolfgang Pieb

October 18, 2017

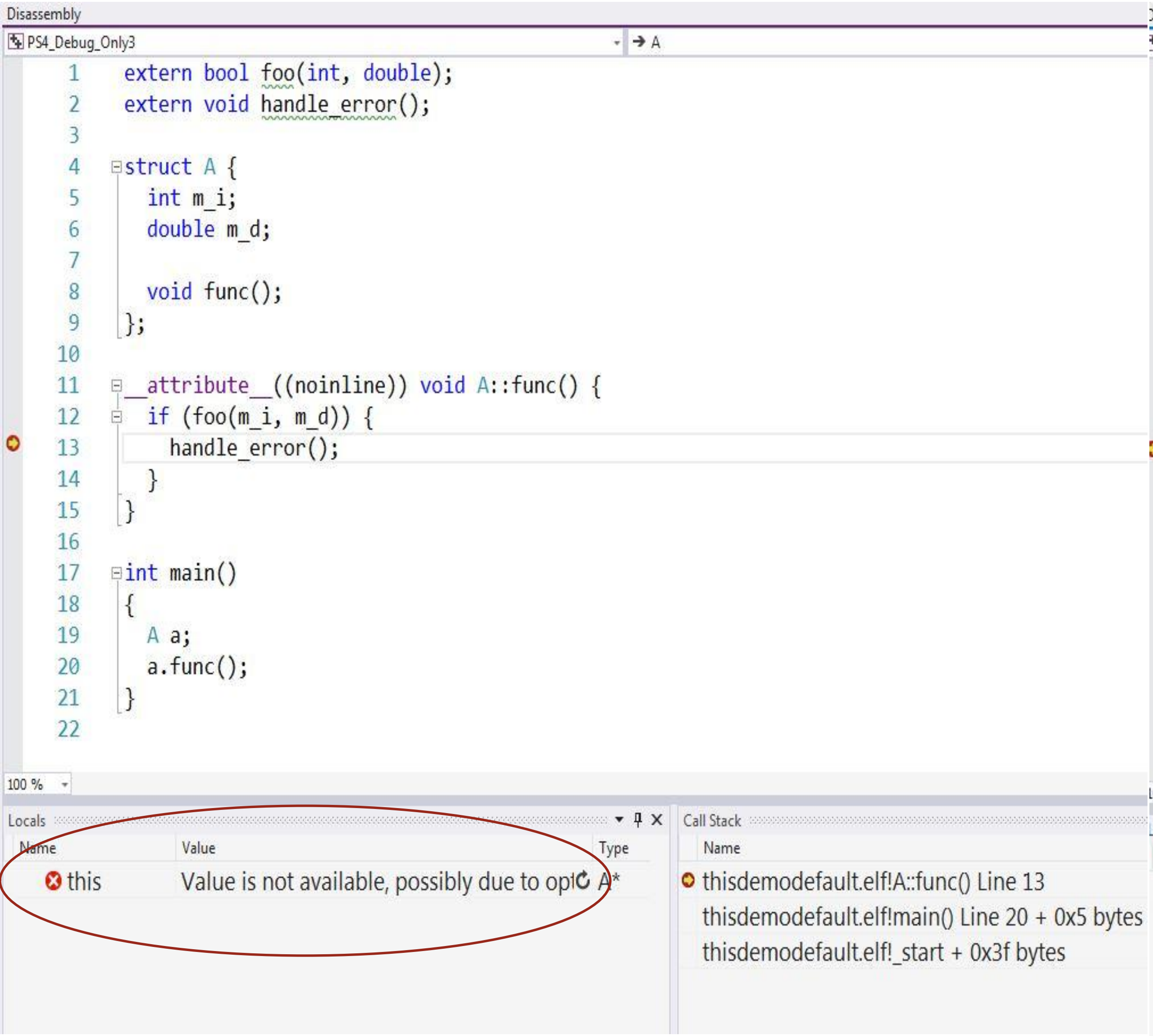
Motivation

- Local variables and parameters (including the `this` pointer) are often optimized away soon after the last point of use.

```
void A::func()
{
  if (<last use of this>) {
    handle_error();              <= the this pointer is not visible in the debugger here
  }
}
```

- By artificially extending the lifetime of these locals and parameters through the end of their lexical scopes we make them visible for debugging purposes.

-O3 -g



```
extern bool foo(int, double);
extern void handle_error();

struct A {
  int m_i;
  double m_d;

  void func();
};

__attribute__((noinline)) void A::func() {
  if (foo(m_i, m_d)) {
    handle_error();
  }
}

int main()
{
  A a;
  a.func();
}
```

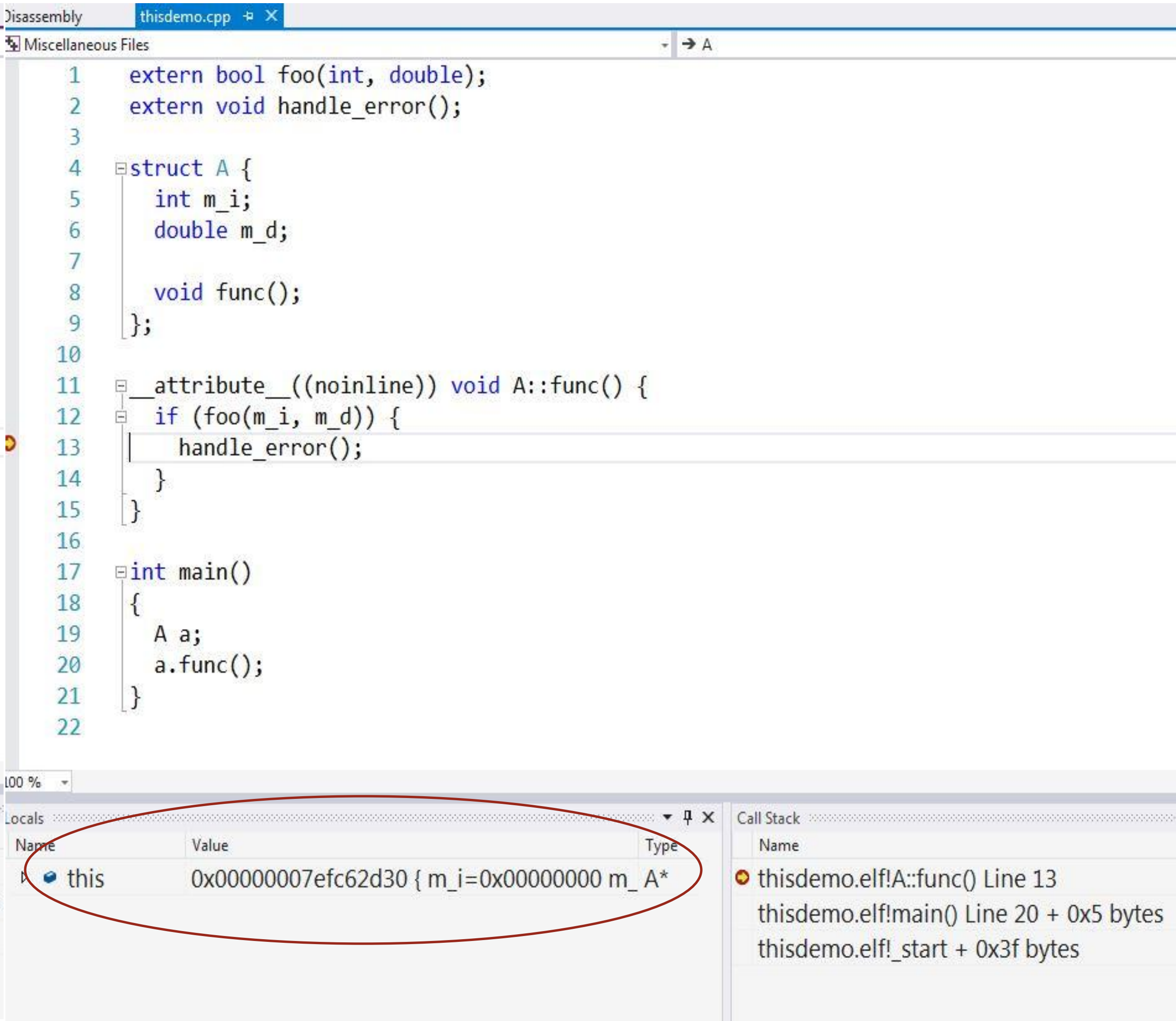
Locals

Name	Value	Type
this	Value is not available, possibly due to opt	A*

Call Stack

Name
thisdemodefault.elf!A::func() Line 13
thisdemodefault.elf!main() Line 20 + 0x5 bytes
thisdemodefault.elf!_start + 0x3f bytes

-O3 -fextend-lifetimes -g



```
extern bool foo(int, double);
extern void handle_error();

struct A {
  int m_i;
  double m_d;

  void func();
};

__attribute__((noinline)) void A::func() {
  if (foo(m_i, m_d)) {
    handle_error();
  }
}

int main()
{
  A a;
  a.func();
}
```

Locals

Name	Value	Type
this	0x00000007efc62d30 { m_i=0x00000000 m_	A*

Call Stack

Name
thisdemo.elf!A::func() Line 13
thisdemo.elf!main() Line 20 + 0x5 bytes
thisdemo.elf!_start + 0x3f bytes

Implementation

- New clang switches -fextend-lifetimes and -fextend-this-ptr
- New llvm intrinsic *llvm.fake.use()*

```
define i32 @_Z3fooi(i32 %param)  {
  …
 call void (...) @llvm.fake.use(i32 %param)
}
```

- The front-end issues calls to llvm.fake.use() for all user-defined local variables and parameters at the end of their respective lexical scopes.

- With -fextend-this-ptr, only the `this` pointer's lifetime is extended.

- Analogous to generating of end-of-lifetime markers.

Example

```
extern void used(double);
extern void usei(int);
double globd;
int globi;

void foo(int param)
{
  double d = globd;
  if (param) {
    int j = globi;
    usei(j);
  }
  used(d);
}
```

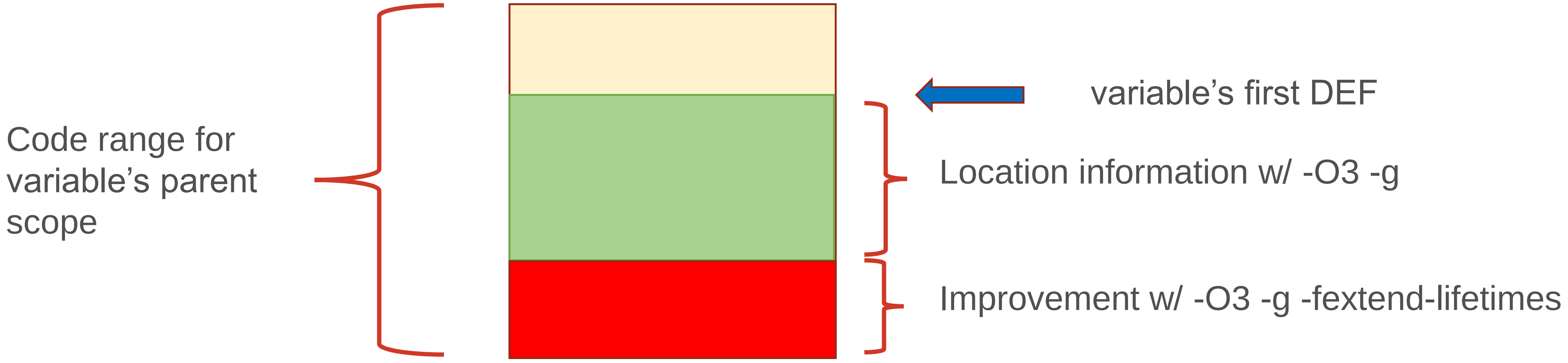
```
define void @foo(i32 %param)  … {
entry:
  %d = load double, double* @globd, align 8
  …
  br i1 %tobool, label %if.end, label %if.then
if.then
 %j = load i32, i32* @globi
  tail call void @usei(i32 %j)
  tail call void (...) @llvm.fake.use(i32 %j)          <= after call to usei()
  br label %if.end
if.end:
  tail call void @used(double %d)
  tail call void (...) @llvm.fake.use(double %d)      <= after call to used()
  tail call void (...) @llvm.fake.use(i32 %param)     <= end of the function
  ret void
}
```

Backend implementation

- llvm.fake.use() is translated into the new FAKE_USE machine op with the intrinsic's argument as operand.
- FAKE_USE is a meta instruction (i.e. does not produce any executable code).
- Some GVN optimizations are suppressed for FAKE_USE operands.
- SROA on pointer operands of FAKE_USE is disabled.
- Type legalization needed to learn about FAKE_USE and its operands.

Effect on debug location information

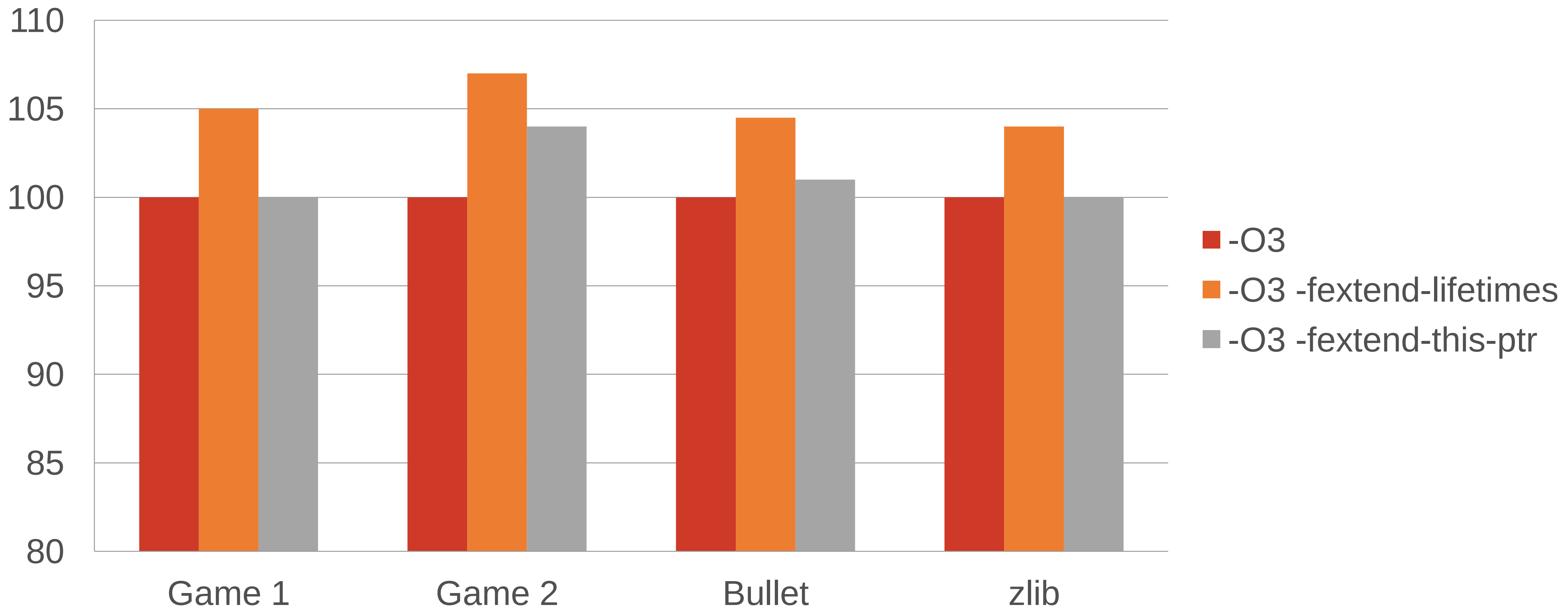
- Measuring coverage by determining the percentage of code that is covered within a variable’s lexical scope.


Code range for variable’s parent scope
variable’s first DEF
Location information w/ -O3 -g
Improvement w/ -O3 -g -fextend-lifetimes

- Game 1: Cumulative coverage improvement by 15%
- Game 2: Cumulative coverage improvement by 14%

Effect on runtime performance

As percentage of execution time



Conclusion

- Debugging of optimized code can be improved by extending the lifetime of local variables and parameters artificially.

- The impact on performance is small (5-7%).

- Positive feedback from users.

- The proposed -Og mode (optimize for debugging) could make use of this functionality.