How to update debug info

in compiler transformations

Adrian Prantl
Vedant Kumar

1. What is debug info?
2. Managing source locations
3. Tooling for writing debug info tests

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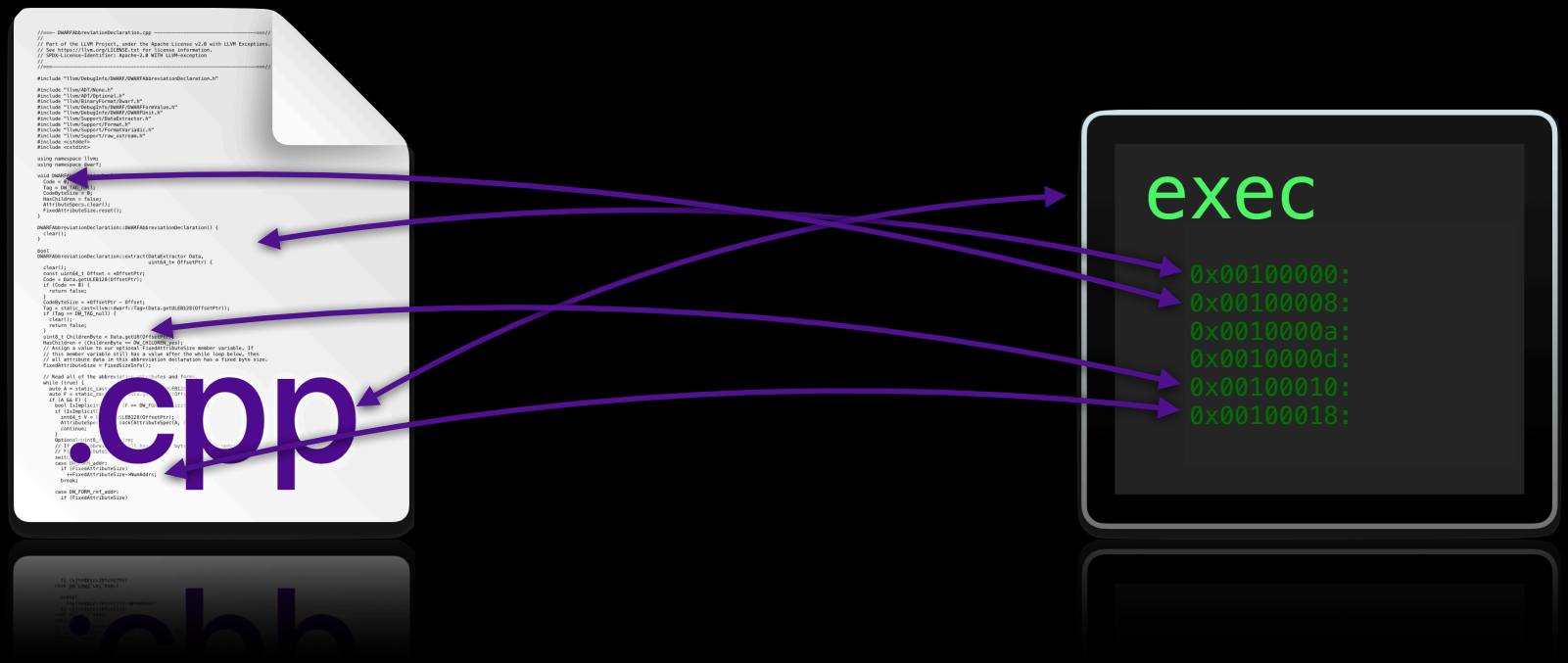
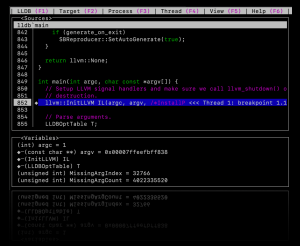


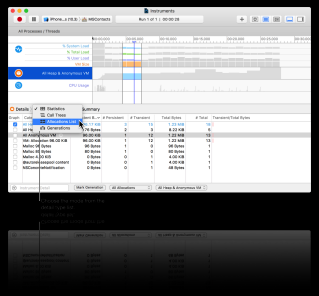
Source Code

Binary

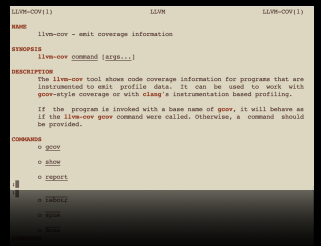
Users of debug info



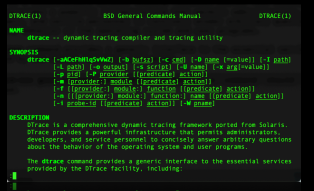
Debuggers



Profilers



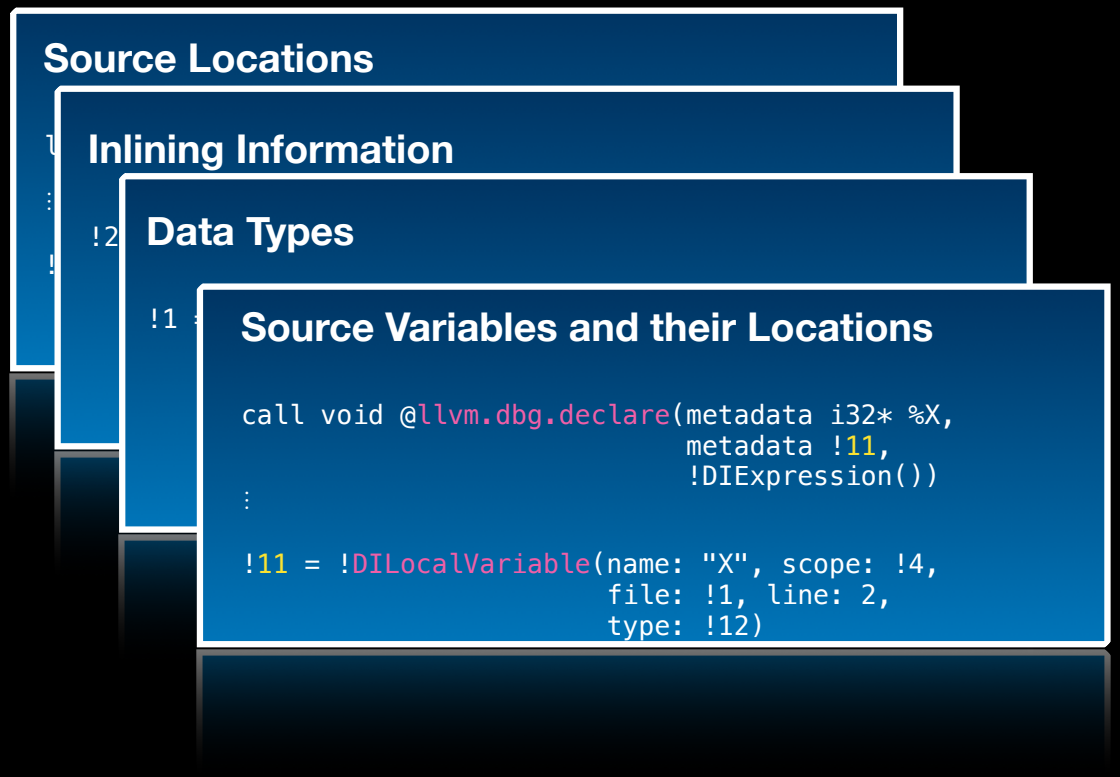
Coverage



Instrumentation

LLVM Debug Info crash course

Kinds of debug information



Kinds of debug information

Source Locations

```
load i32*, i32** %x.addr, !dbg !14
⋮
!14 = !DILocation(line: 22, column: 4, scope: !0)
```

Source Variables and their Locations

```
call void @llvm.dbg.declare(metadata i32* %X,
                            metadata !11,
                            !DIExpression())
⋮
!11 = !DILocalVariable(name: "X", scope: !4,
                       file: !1, line: 2,
                       type: !12)
```

Inlining Information

```
!23 = !DILocation(line: 2, column: 8, scope: !24,
                  inlinedAt: !25)
```

Data Types

```
!1 = !DIBasicType(name: "int", size: 32,
                  align: 32, encoding: DW_ATE_signed))
```

Kinds of debug information

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Source Variables and their Locations

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                       file: !1, line: 2,
                       type: !12)
```

Stay tuned!

Inlining Information

```
!23 = !DILocation(line: 2, column: 8, scope: !24,
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```

Don't worry about this

Data Types

```
!1 = !DIBasicType(name: "int", size: 32,
                  align: 32, encoding: DW_ATE_signed))
```

Don't worry about this

1. What is debug info?
2. Managing source locations
3. Tooling for writing debug info tests

Source Locations

- Debug info maps instructions to source locations
- An instruction `DebugLoc` contains **file**, **line/column**, **scope** and **inline** information
- Represented as `DILocation` LLVM metadata

```
load i32*, i32** %x.addr, !dbg !14
⋮
!14 = !DILocation(line: 22, column: 4, scope: !0)
```

Debug info in optimized programs

Compiler's job is to delete, reorder, merge, sink/hoist, clone, & create instructions to maximize performance.

How to keep a meaningful mapping to the source code?

- Spoiler alert. It's not generally possible to unambiguously map source location to optimized code.
  - Different consumers have different priorities.
  - Treat debug info preservation as an optimization problem.

Principles for updating debug info

Principles for updating debug info

1. Make no misleading statements about the program
   - An optimized version of a program should appear to take the same conditions as the unoptimized version (assuming full determinism)
   - Don't speculate! No info is better than info that is only correct sometimes.

Principles for updating debug info

1. Make no misleading statements about the program
   - An optimized version of a program should appear to take the same conditions as the unoptimized version (assuming full determinism)
   - Don't speculate! No info is better than info that is only correct sometimes.
2. Provide as much information as possible
   - When it's not misleading to preserve a source location, do so!

What *can* the compiler do?

Our menu of options

- 🤗 Keep the original location
- 🪖 Merge
- 🗑️ Delete

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What *can* the compiler do?

Our menu of options

🤗 Keep the original location

🤿 Merge

🗑️ Delete

Scopes correspond to nested {} in C++ and determine which variables are visible.

```
!DILocation(line: 22, column: 4, scope: !25)
!DILocation(line: 25, column: 8, scope: !25)
```

∩

```
!DILocation(line:  0, column: 0, scope: !25)
```

Lines start counting at 1.
Line 0 denotes «*no source location*».

What *can* the compiler do?

Our menu of options

🤗 Keep the original location

 Merge

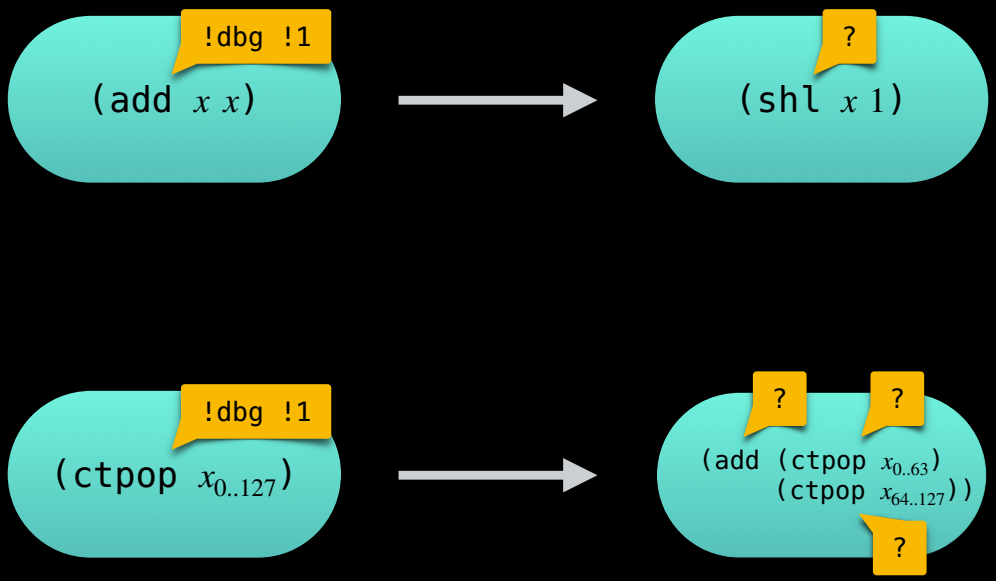
🗑️ Delete

```
%foo = add i32 %i, i32 1, !dbg !15
```

Block-local transformations

✅ Profilers
⚠️ Debuggers

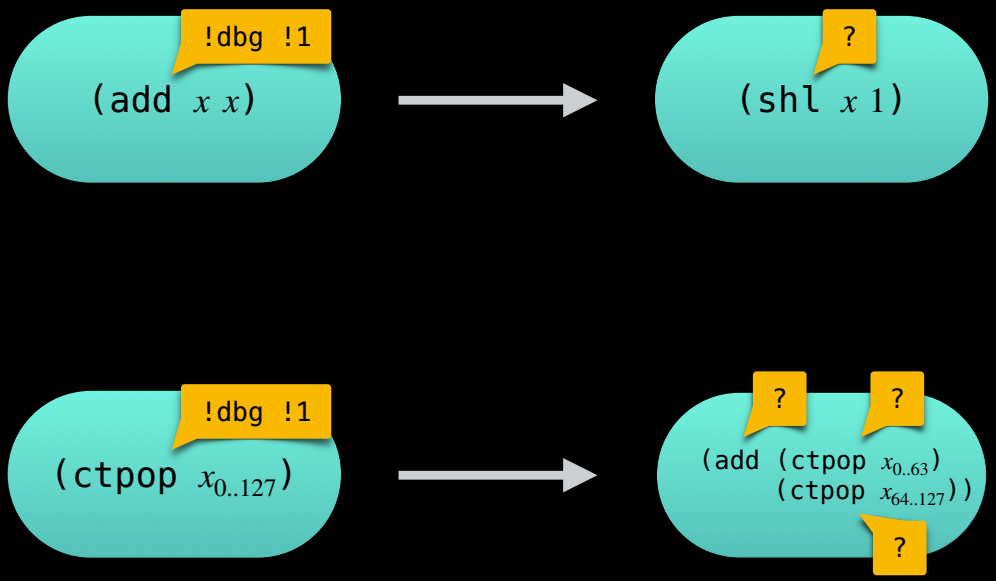
Replace or Expand



Examples taken from DAGCombine and Legalizer.

Replace or Expand

Try to keep the debug location.

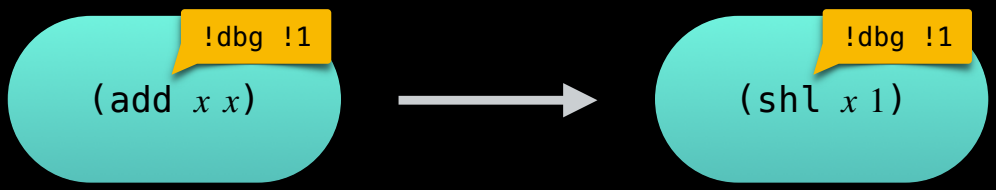


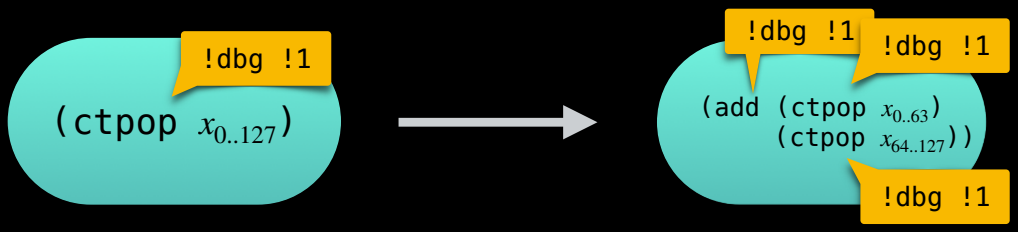
Possible Actions

1. Keep
2. Merge
3. Delete

Replace or Expand

Try to keep the debug location.





Would keeping create misleading information?

Possible Actions

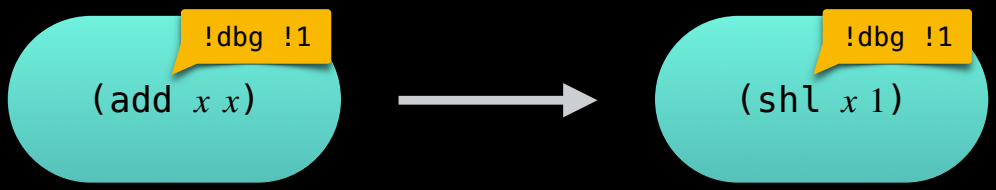
1. Keep
2. Merge
3. Delete

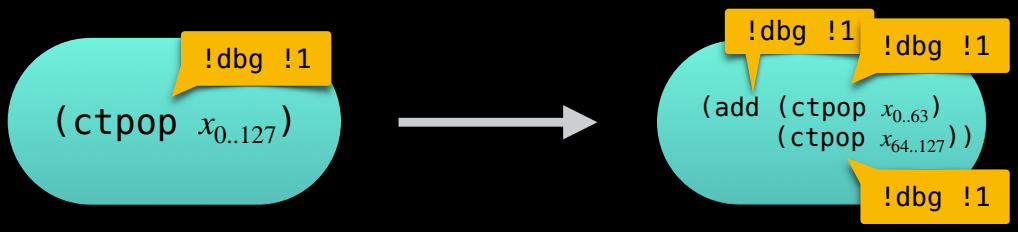
Principles

1. Don't mislead!
2. Preserve!

Replace or Expand

Try to keep the debug location.





Does not change conditions which appear taken. Preserve!

Possible Actions

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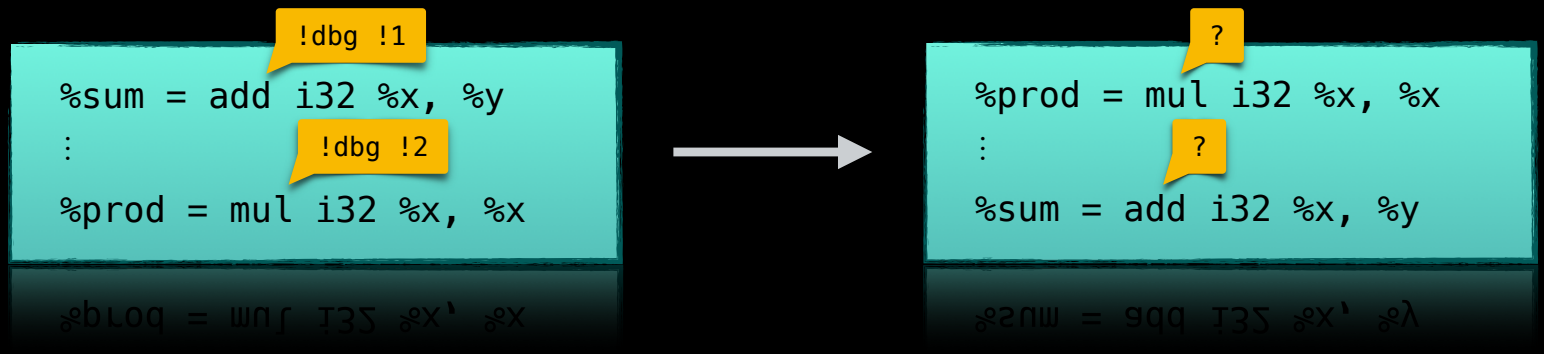
Instruction reordering



Example taken from the MI instruction scheduler.

Instruction reordering

Try to keep the debug location.

Possible Actions

1. Keep
2. Merge
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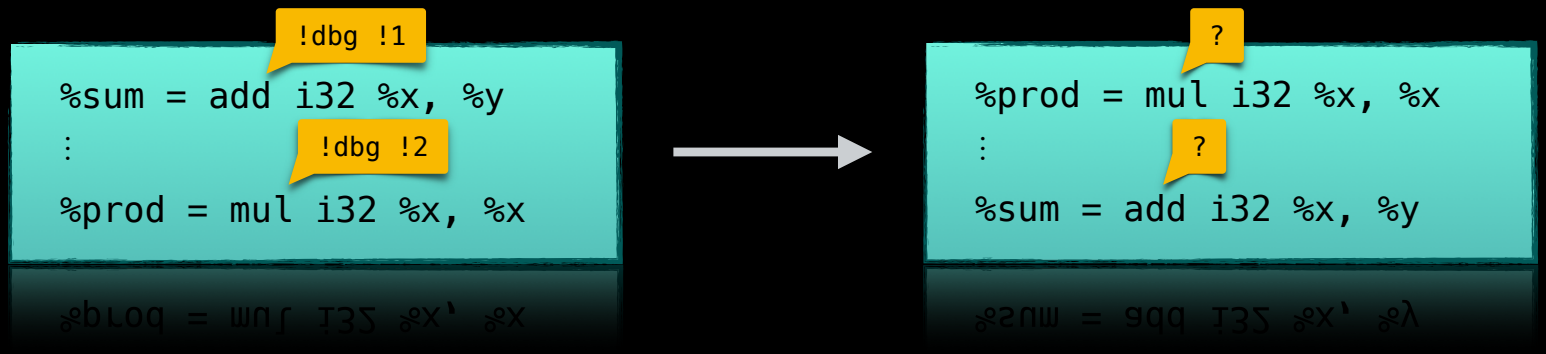
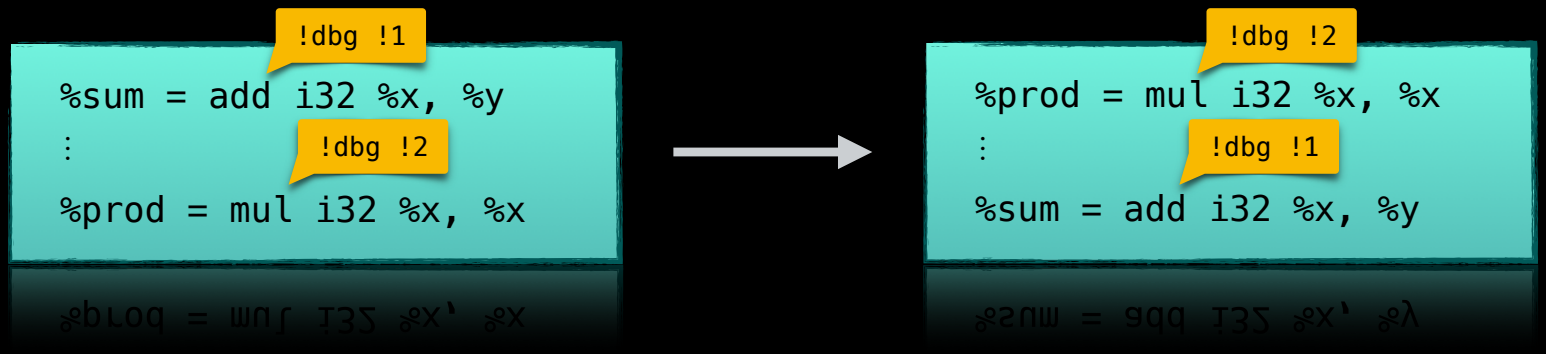


Instruction reordering

Try to keep the debug location.



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Instruction reordering

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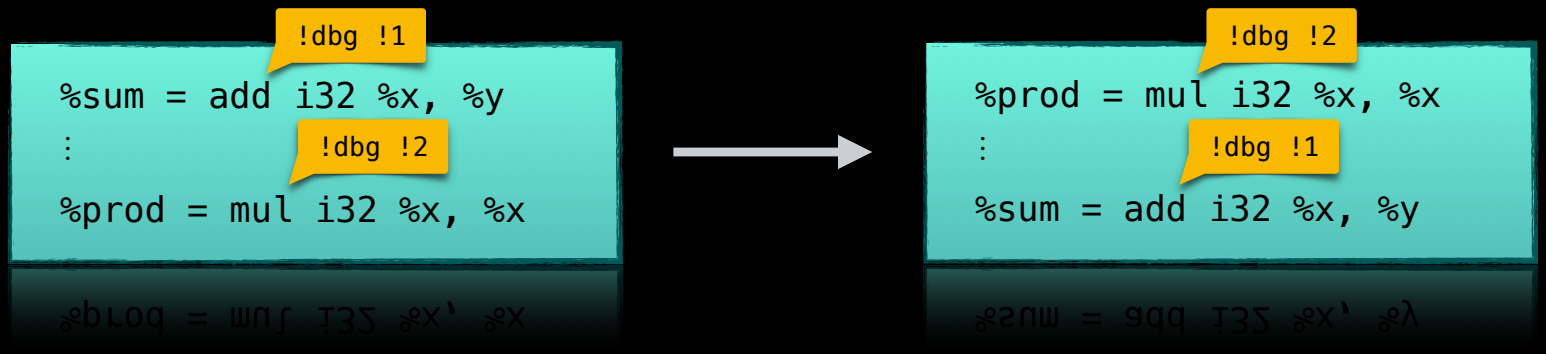

Possible Actions

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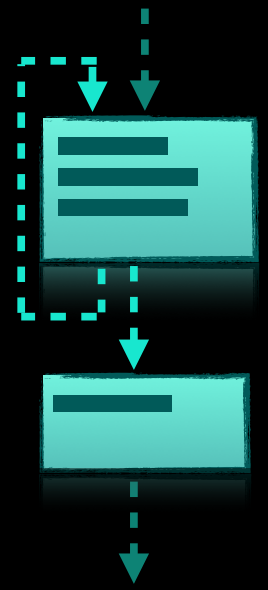
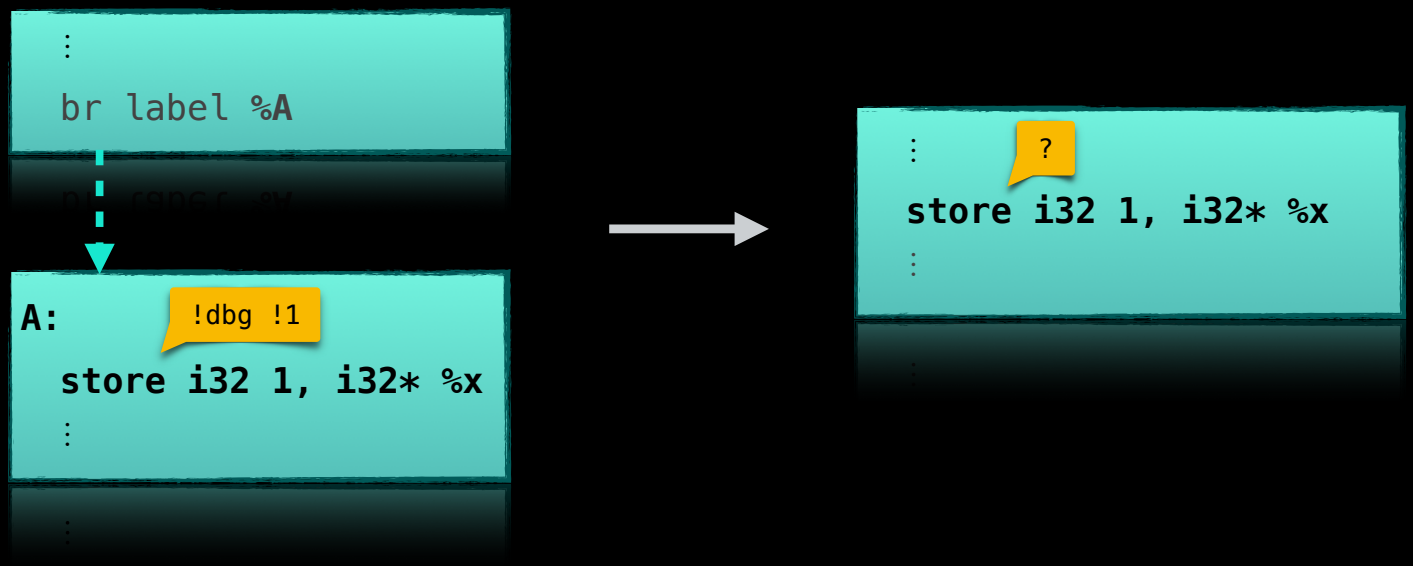
Does not change conditions which appear taken. Preserve!

Inter-block transformations



⚠ Profilers
⚠ Debuggers

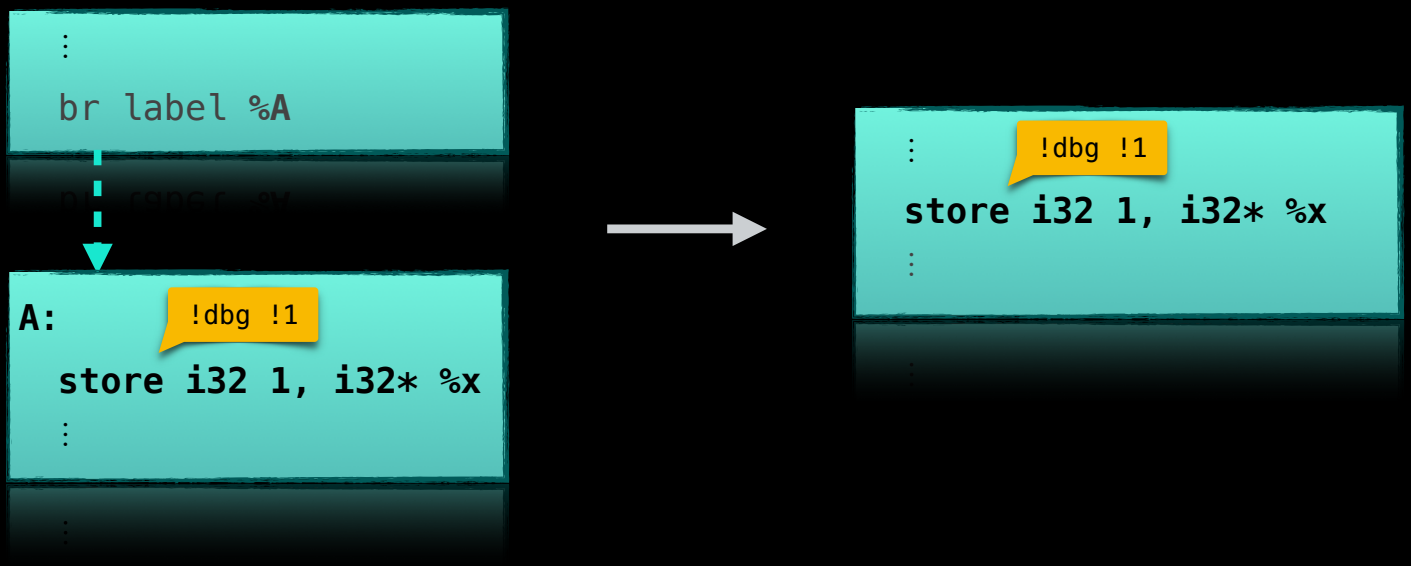
Fold block into unique predecessor



Example taken from SimplifyCFG.

Fold block into unique predecessor

Try to keep the debug location.



Possible Actions

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Principles

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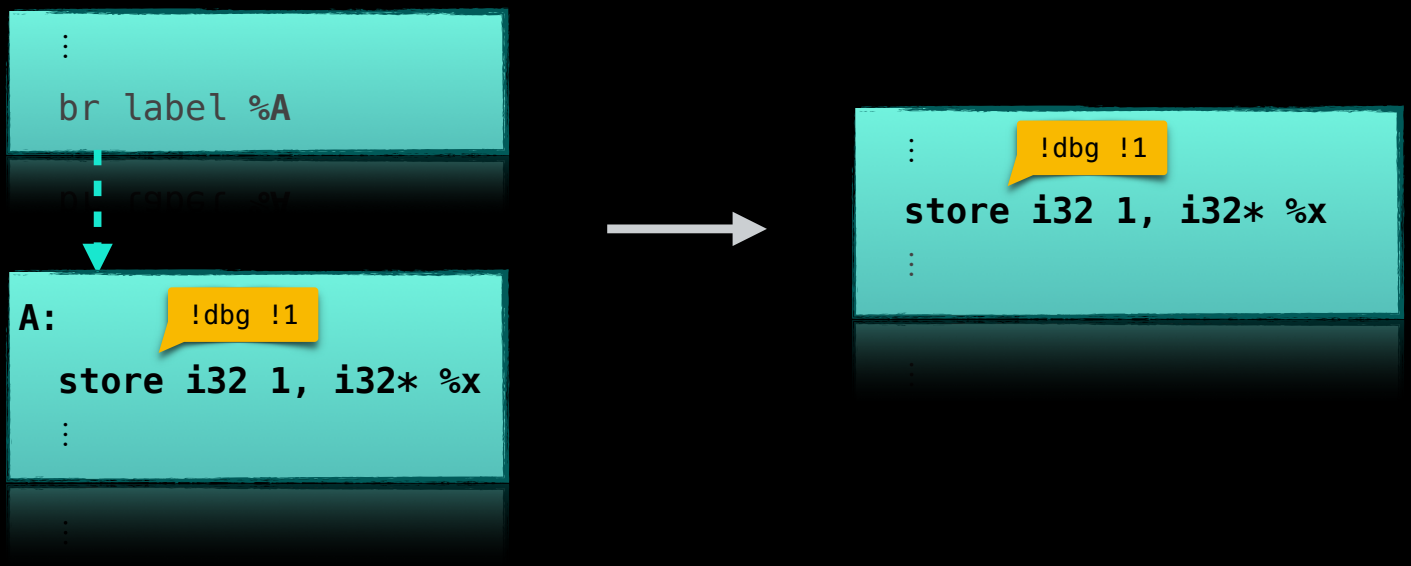
Fold block into unique predecessor

Try to keep the debug location.



Does not change conditions which appear taken. Preserve!

Possible Actions

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2. Merge
3. Delete

Principles

1. Don't mislead!
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Merging loads/stores

Example taken from MergedLoadStoreMotion.

Merging loads/stores

Try to keep the debug locations.

Possible Actions

1. Keep
2. Merge
3. Delete

Merging loads/stores

Try to keep the debug locations.

Can't do it yet.

Debug info consumers need to pick one location.

Possible Actions

1. Keep
2. Merge
3. Delete

Principles

1. Don't mislead!
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Merging loads/stores

Try to merge the debug locations.

Possible Actions

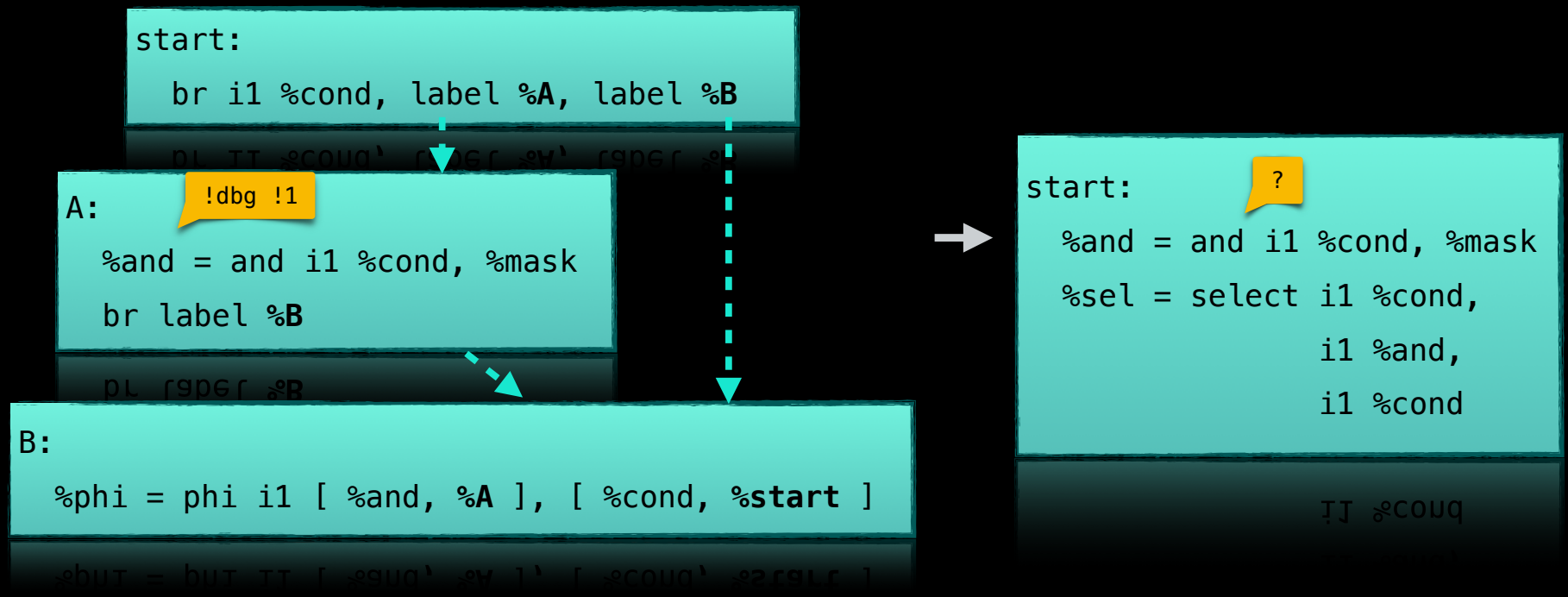
1. Keep
2. Merge
3. Delete

Principles

1. Don't mislead!
2. Preserve!

Use `Instruction::applyMergedLocation()`.

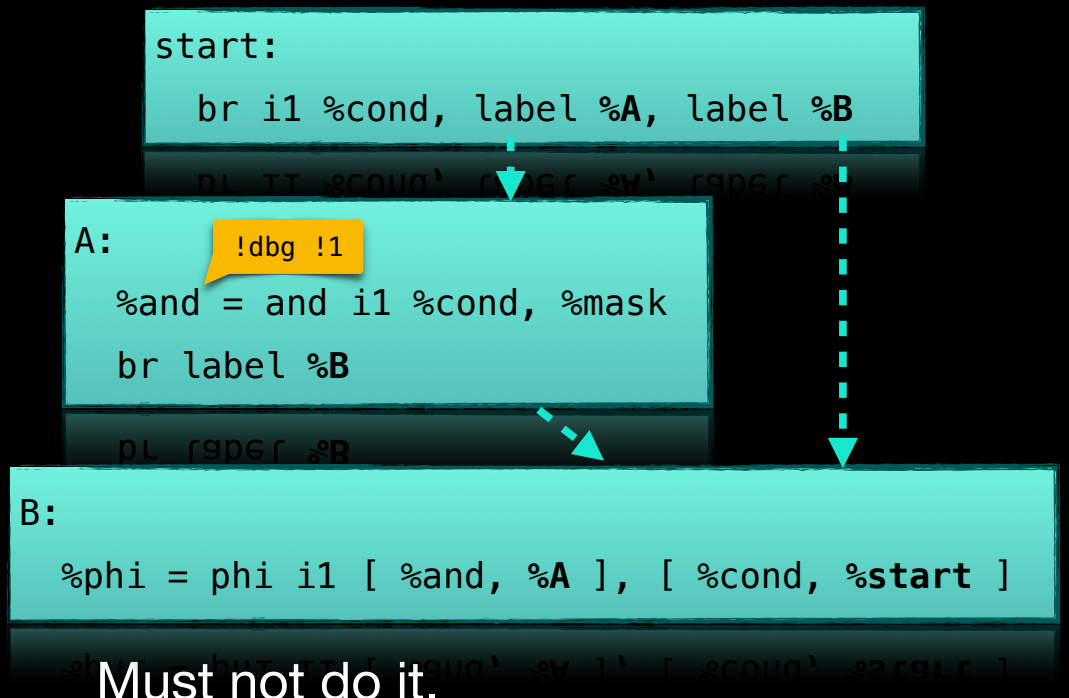
Speculative execution

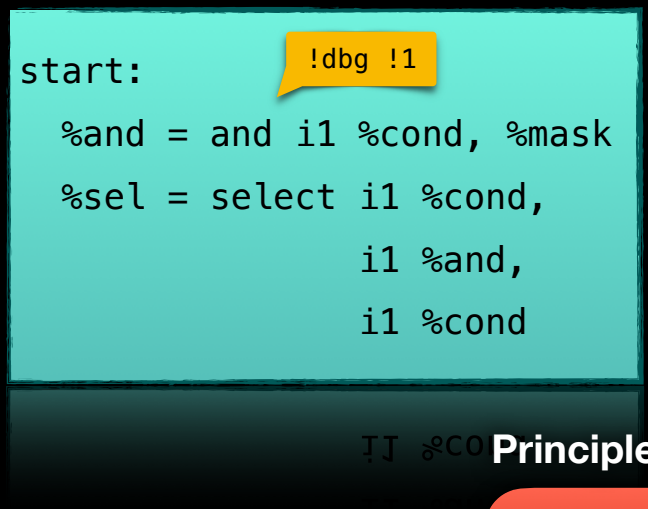


Example taken from SimplifyCFG.

Speculative execution

Try to keep the debug location.





Must not do it.

Makes it look like *%cond* is always `true`!

Possible Actions

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2. Merge
3. Delete

Principles

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Speculative execution

Try to merge the debug location.

Possible Actions

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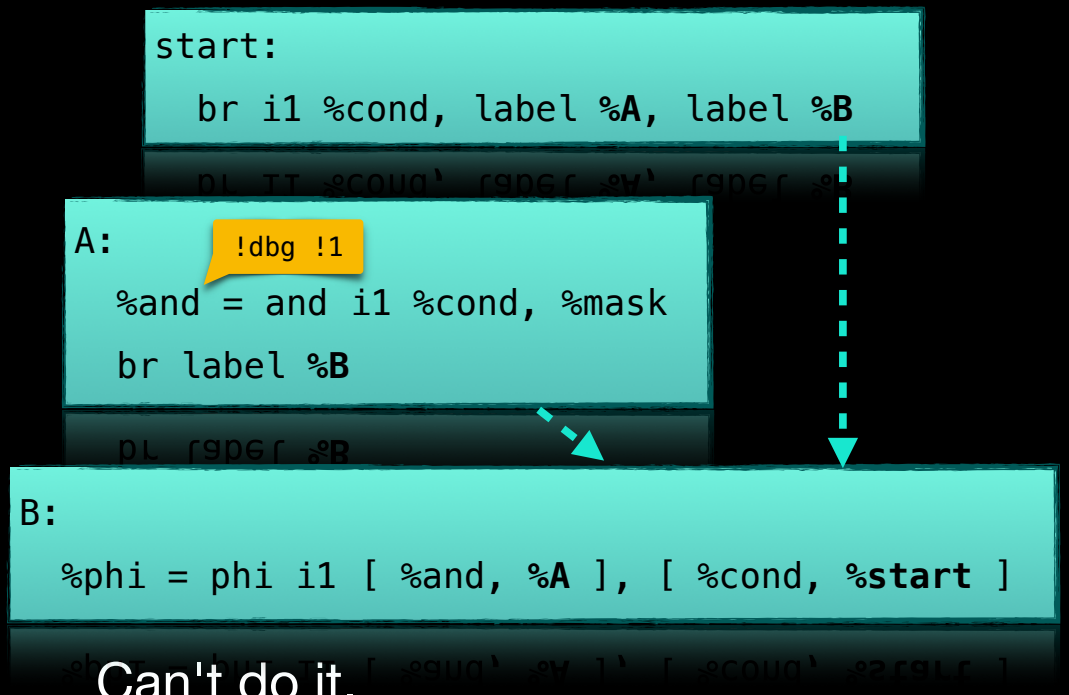
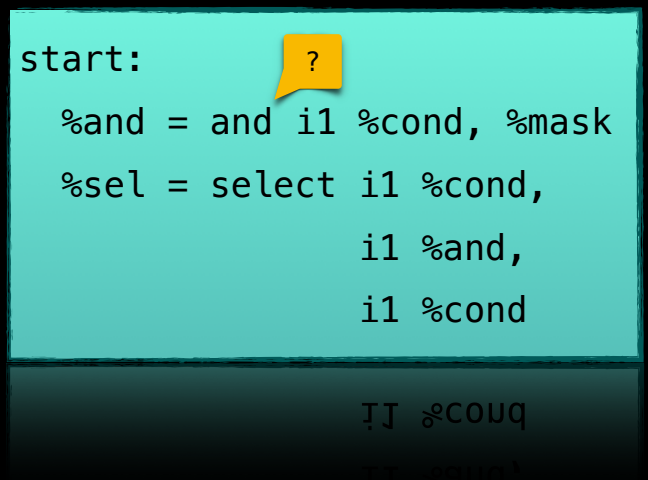


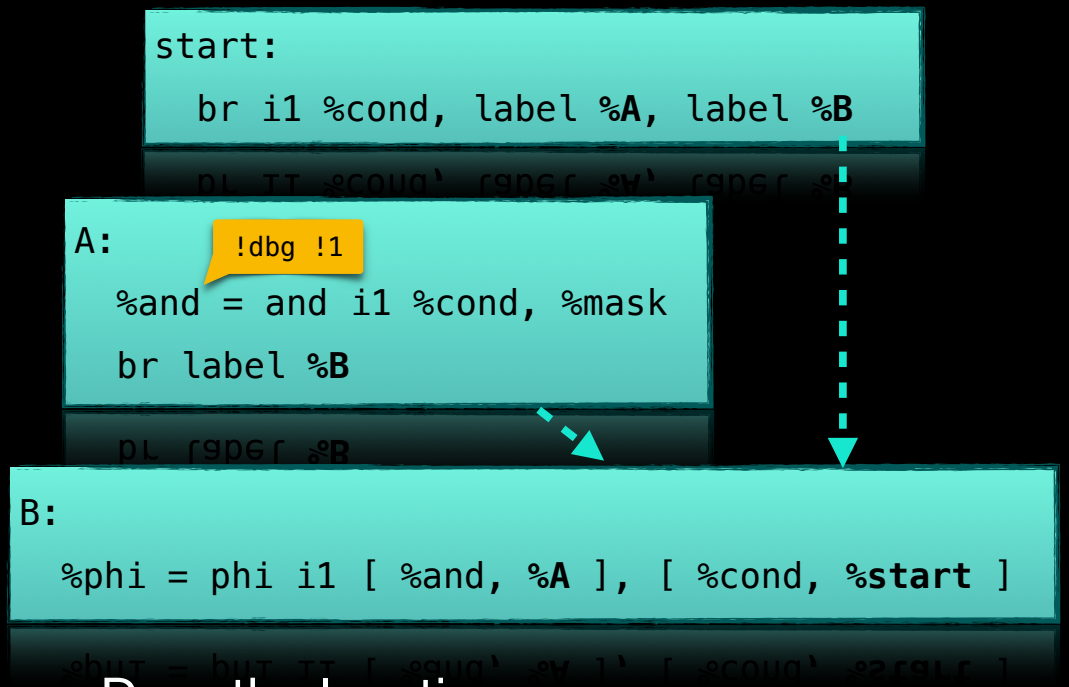


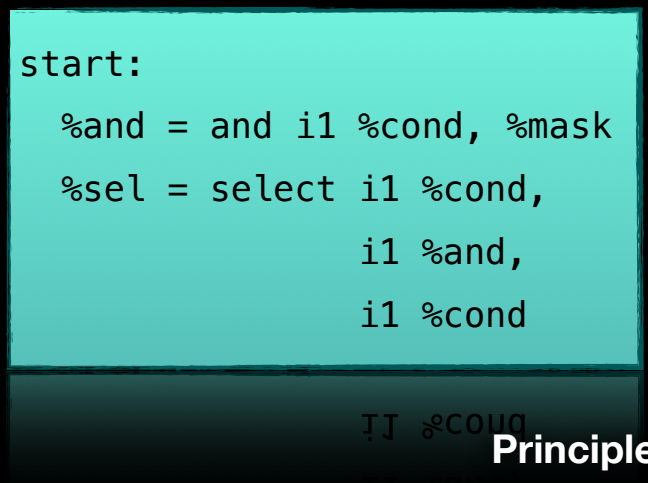
Can't do it.

Nothing to merge the location with.

Speculative execution

Try to merge the debug location.





Drop the location.

Use `Instruction::dropLocation()`.

Possible Actions

1. Keep
2. Merge
3. Delete

Principles

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1. What is debug info?
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3. Tooling for writing debug info tests

Requirements for a debug info test

- A debug info test validates source locations after a transformation
- Requires reduced IR to exercise the correct transformation
- Requires reduced debug info metadata (possibly initially generated by a frontend)

Converting tests into debug info tests

- Easier than ever to test IR or MIR transformations with debug info present
- Use `opt -debugify` to attach debug info metadata to IR instructions
- Use `llc -run-pass=mir-debugify` to do the same to MIR instructions
- MIR debugify can also be applied during GlobalISel
- Documentation
  - https://llvm.org/docs/HowToUpdateDebugInfo.html

Pre-debugify IR

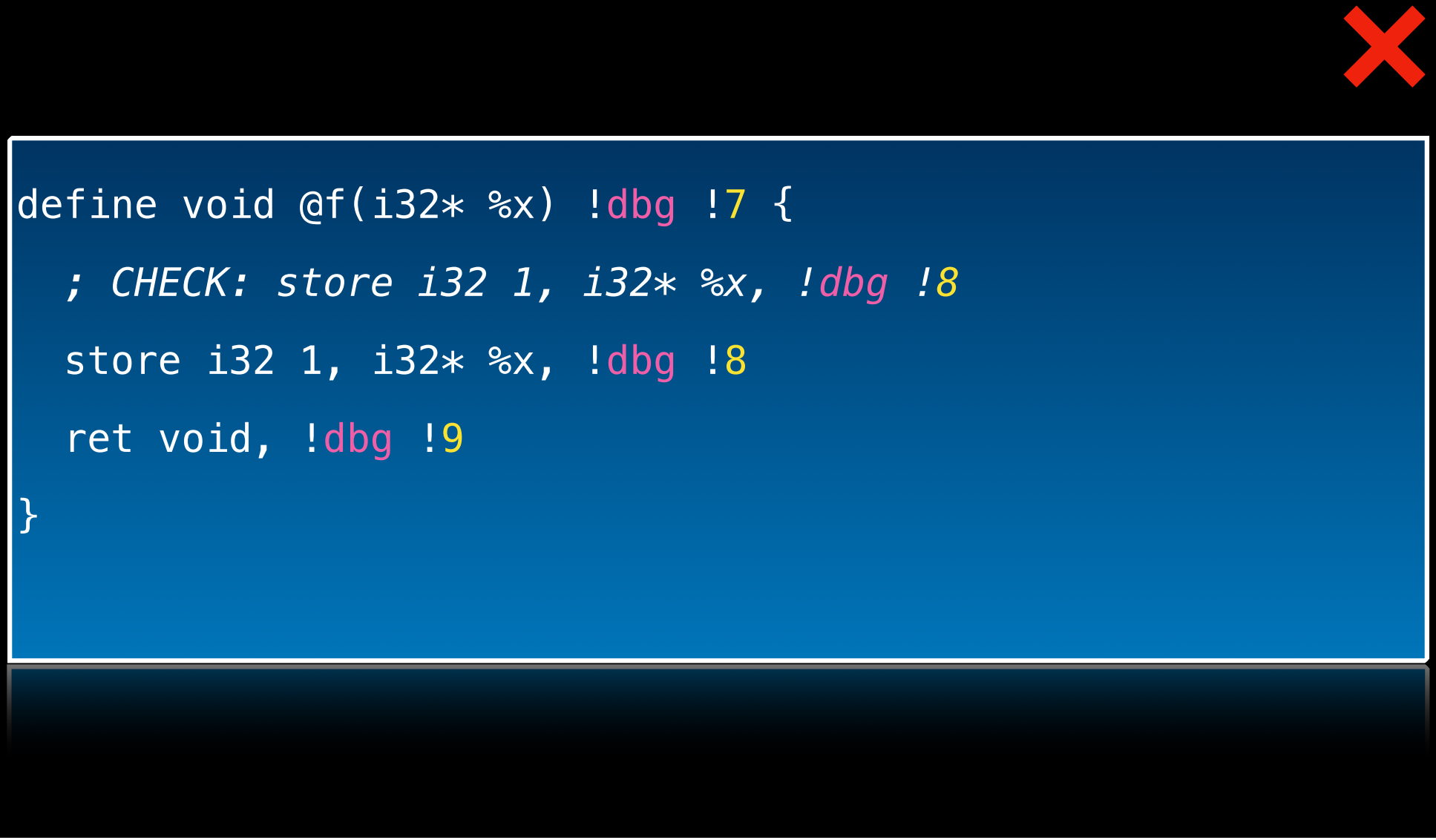
```
define void @f(i32* %x) {
  store i32 1, i32* %x
  ret void
}
```

After `opt -debugify -debugify-level=locations`

```
define void @f(i32* %x) !dbg !7 {
  store i32 1, i32* %x, !dbg !8
  ret void, !dbg !9
}
!7 = !DISubprogram(name: "f", ...)
!8 = !DILocation(line: 1, ...)
!9 = !DILocation(line: 2, ...)
```

Writing a *good* debug info test

- Check that the *correct* location is used, not just *any* location
- Do not hardcode metadata numbers into `CHECK` lines (they change!)
- Minimize the amount of metadata present (debugify helps with this)
  - Try `opt -strip -debugify` to pare down to synthetic locations only



```
define void @f(i32* %x) !dbg !7 {
  ; CHECK: store i32 1, i32* %x, !dbg !8
  store i32 1, i32* %x, !dbg !8
  ret void, !dbg !9
}
```

```
define void @f(i32* %x) !dbg !7 {
  ; CHECK: store i32 1, i32* %x, !dbg ![[storeLoc:[0-9]+]]
  store i32 1, i32* %x, !dbg !8
  ret void, !dbg !9
}
; CHECK: ![[storeLoc]] = !DILocation(line: 1
```

Recap

- Debug info has a large and diverse set of applications
- Every transformation can affect the source location mapping
- Simple guidelines available to help manage source locations
- Tools available to help write clean IR or MIR-based debug info tests

https://llvm.org/docs/HowToUpdateDebugInfo.html