Generalized Mem2Reg for MLIR and how to use it

Théo Degioanni

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Convert non-SSA memory locations into SSA values.

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In LLVM: convert stack alloca to SSA values.

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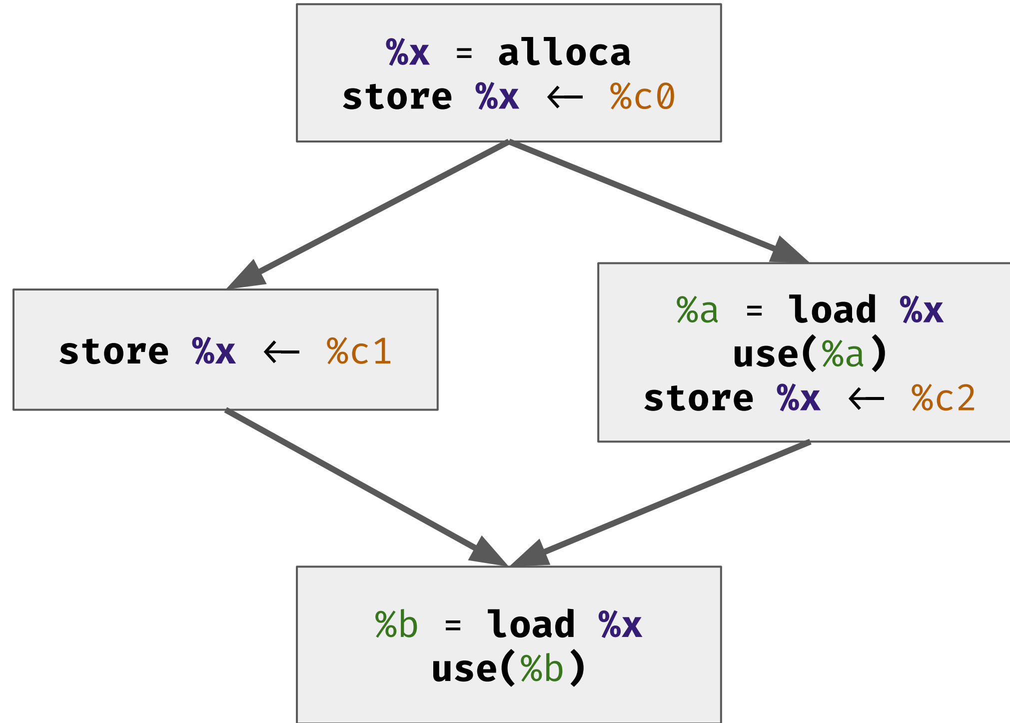

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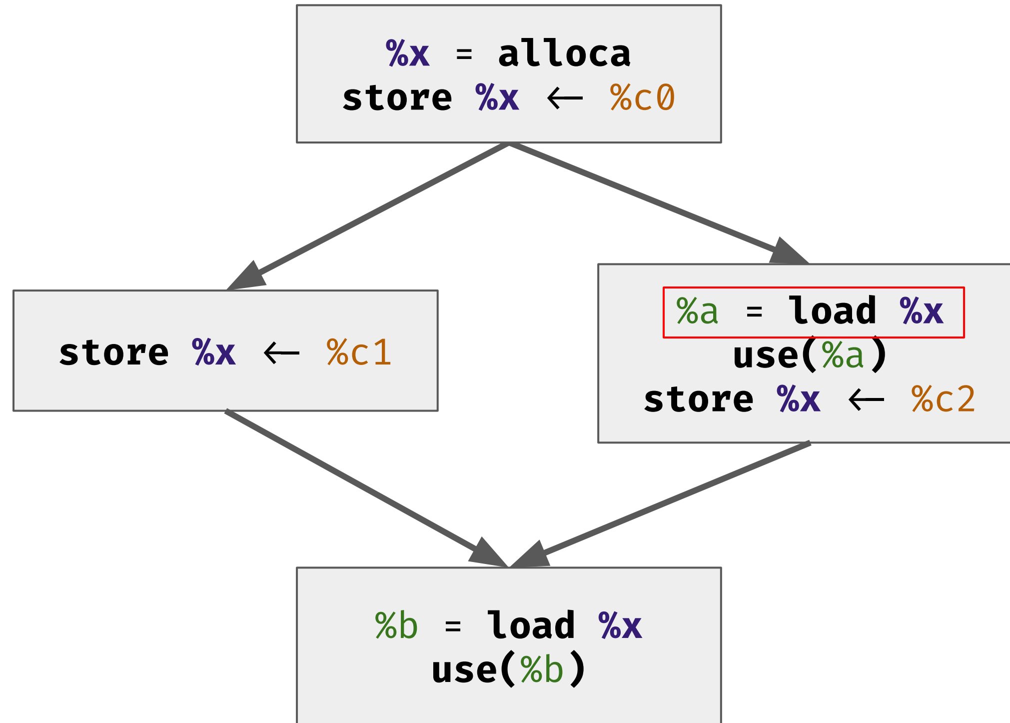

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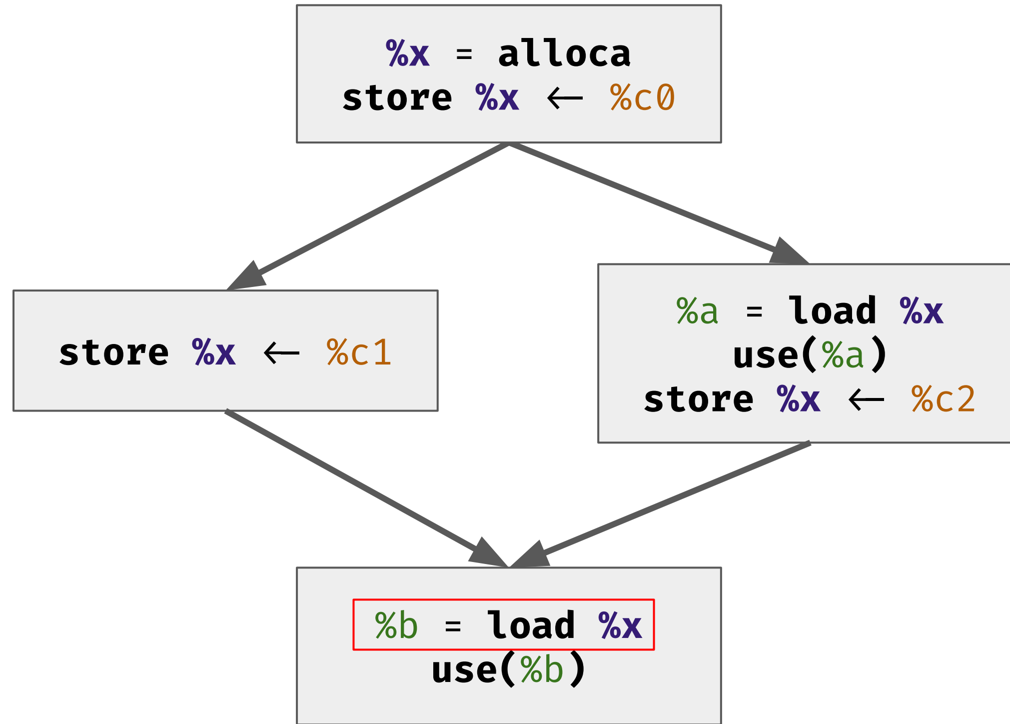

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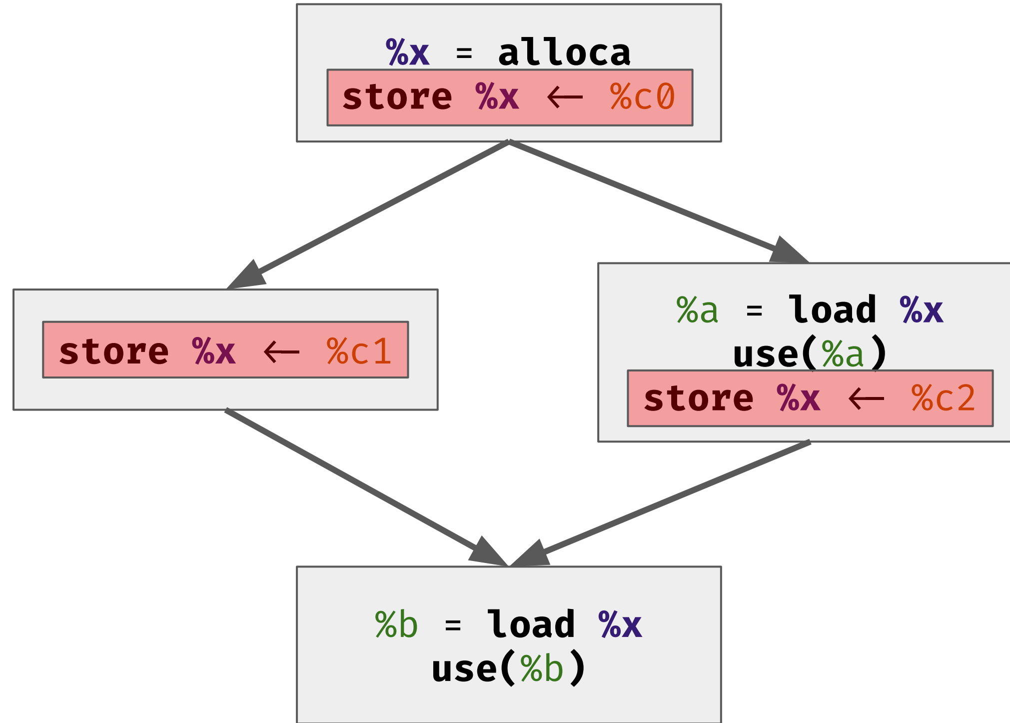

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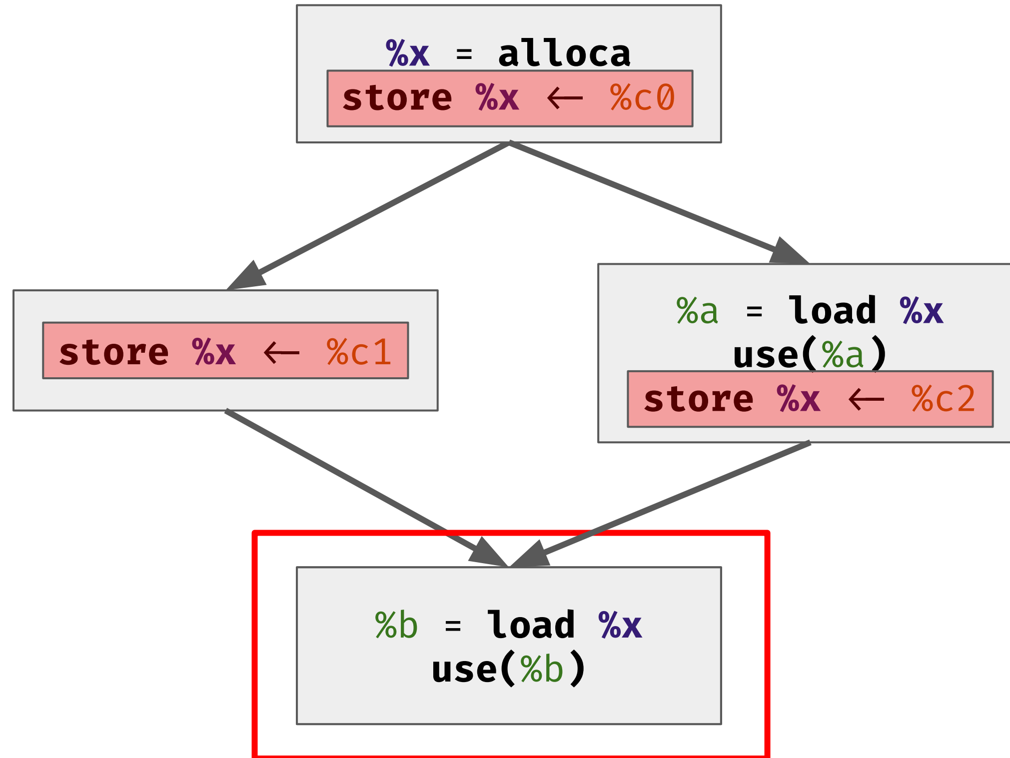

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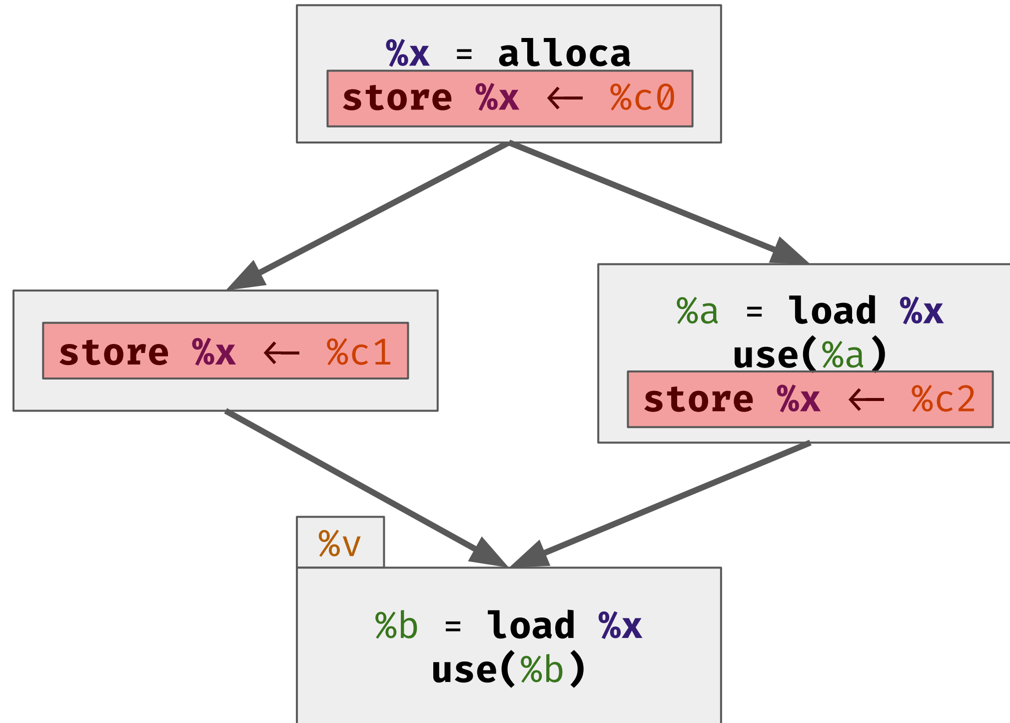

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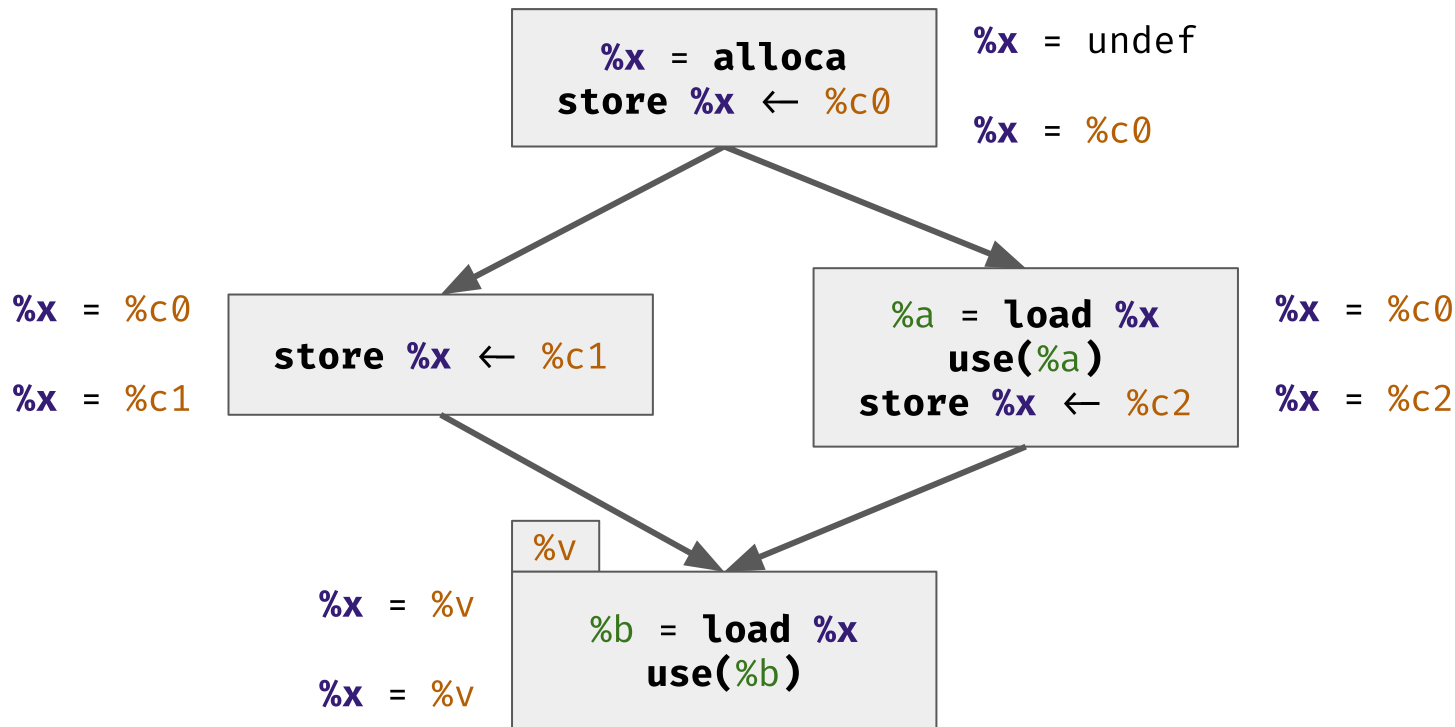

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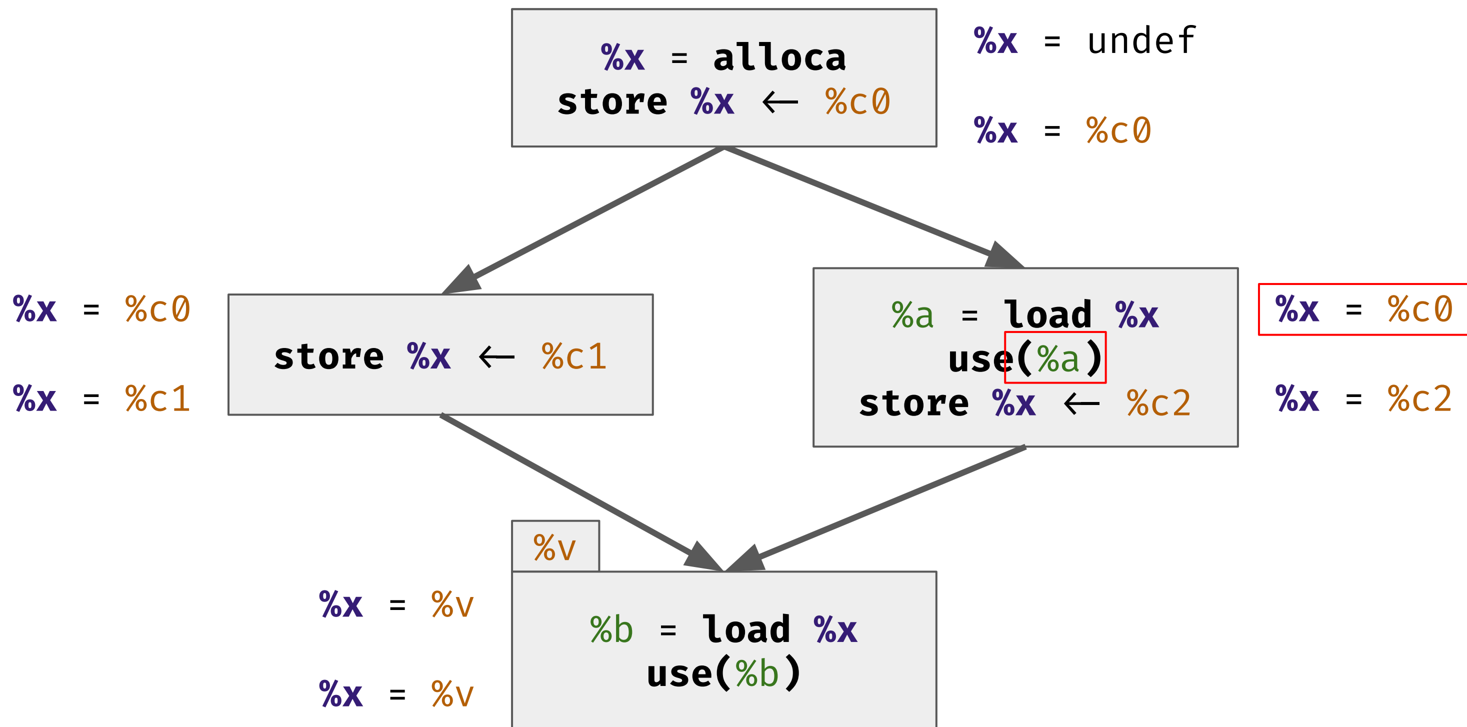

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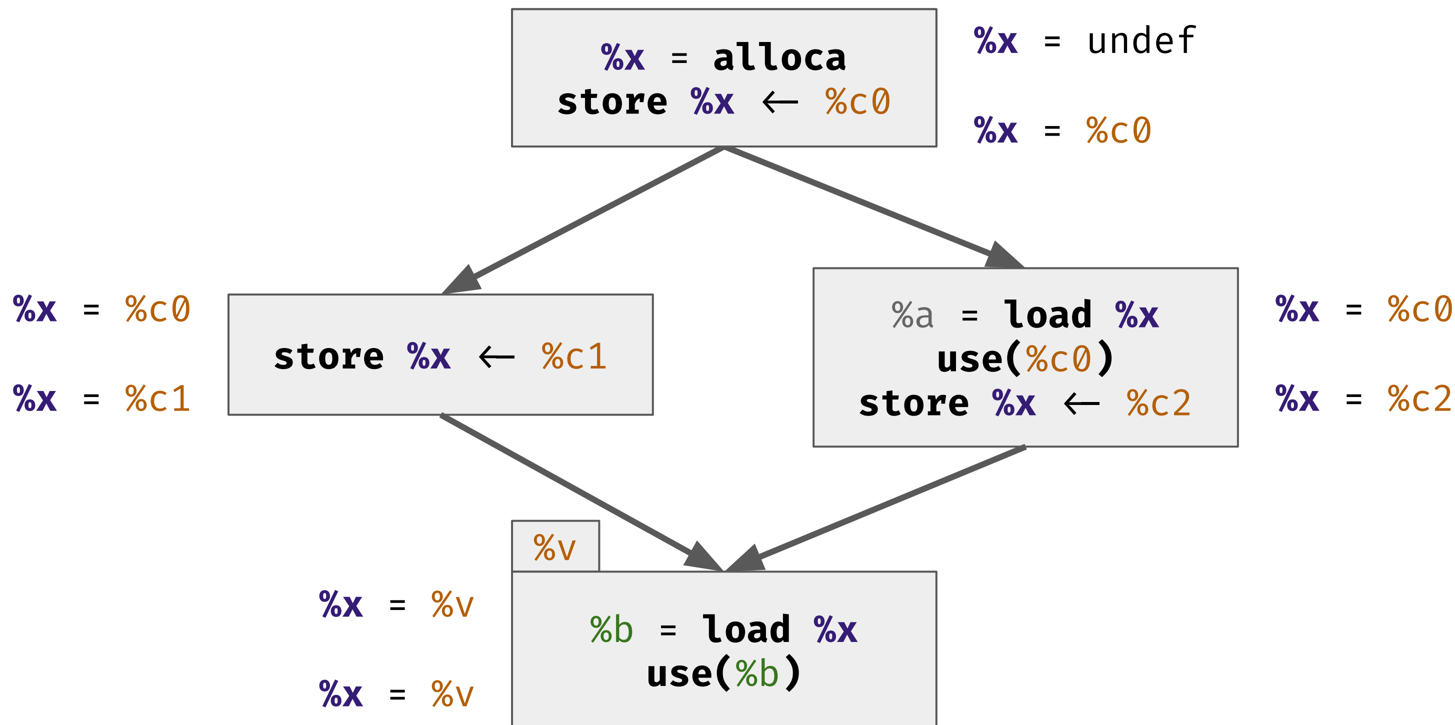

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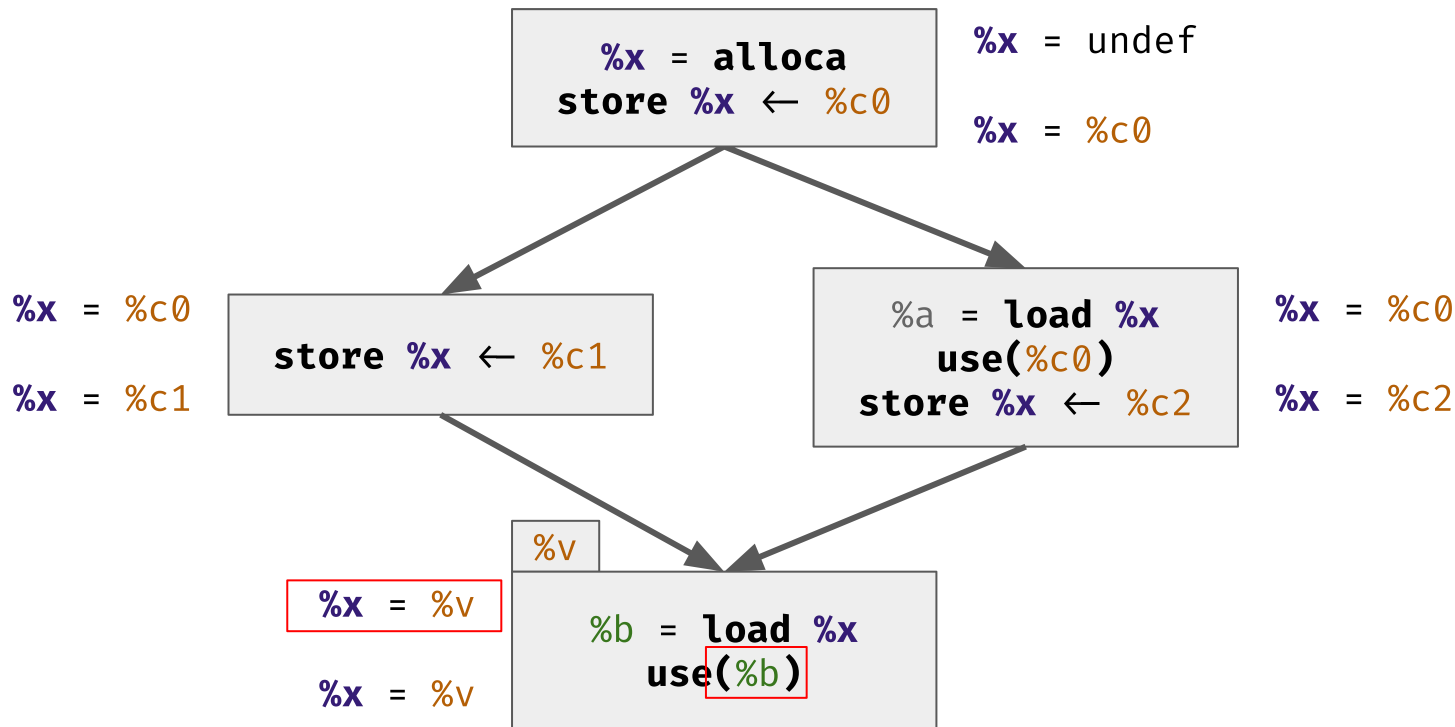

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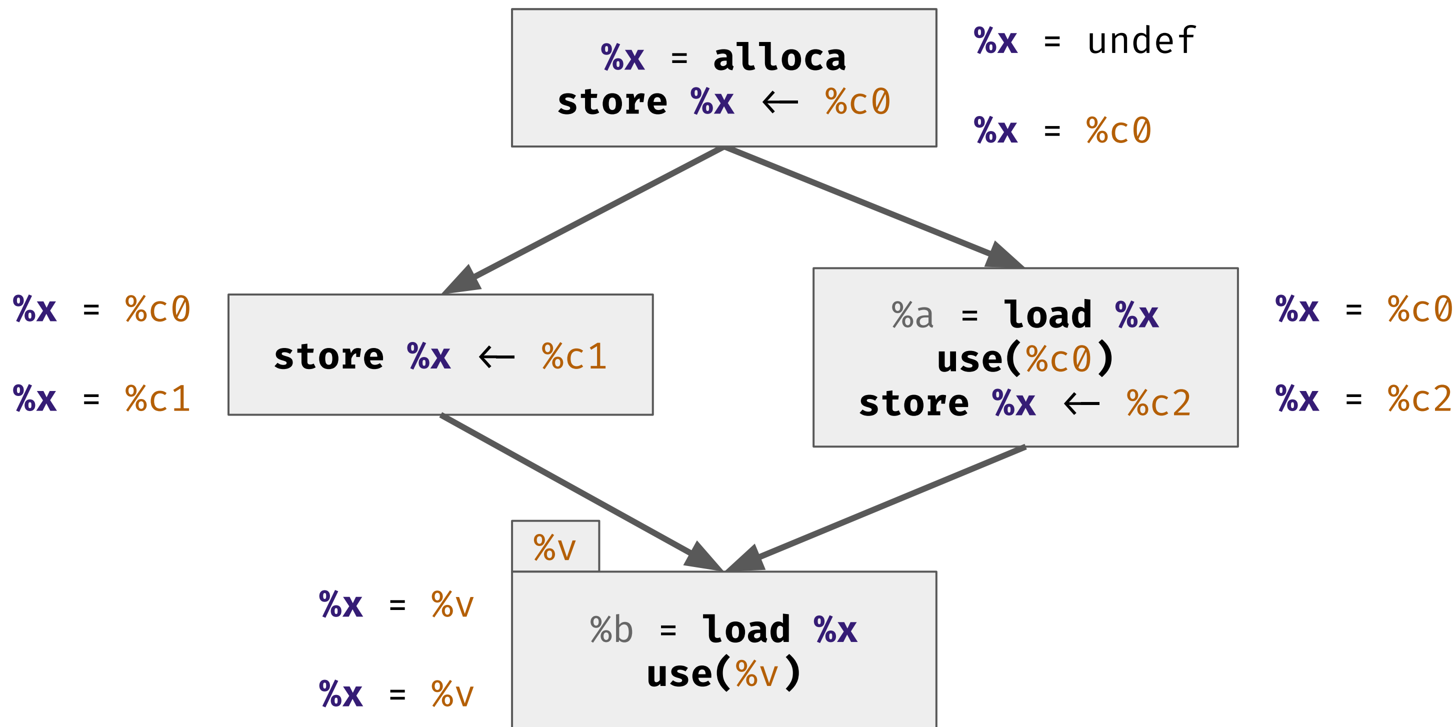

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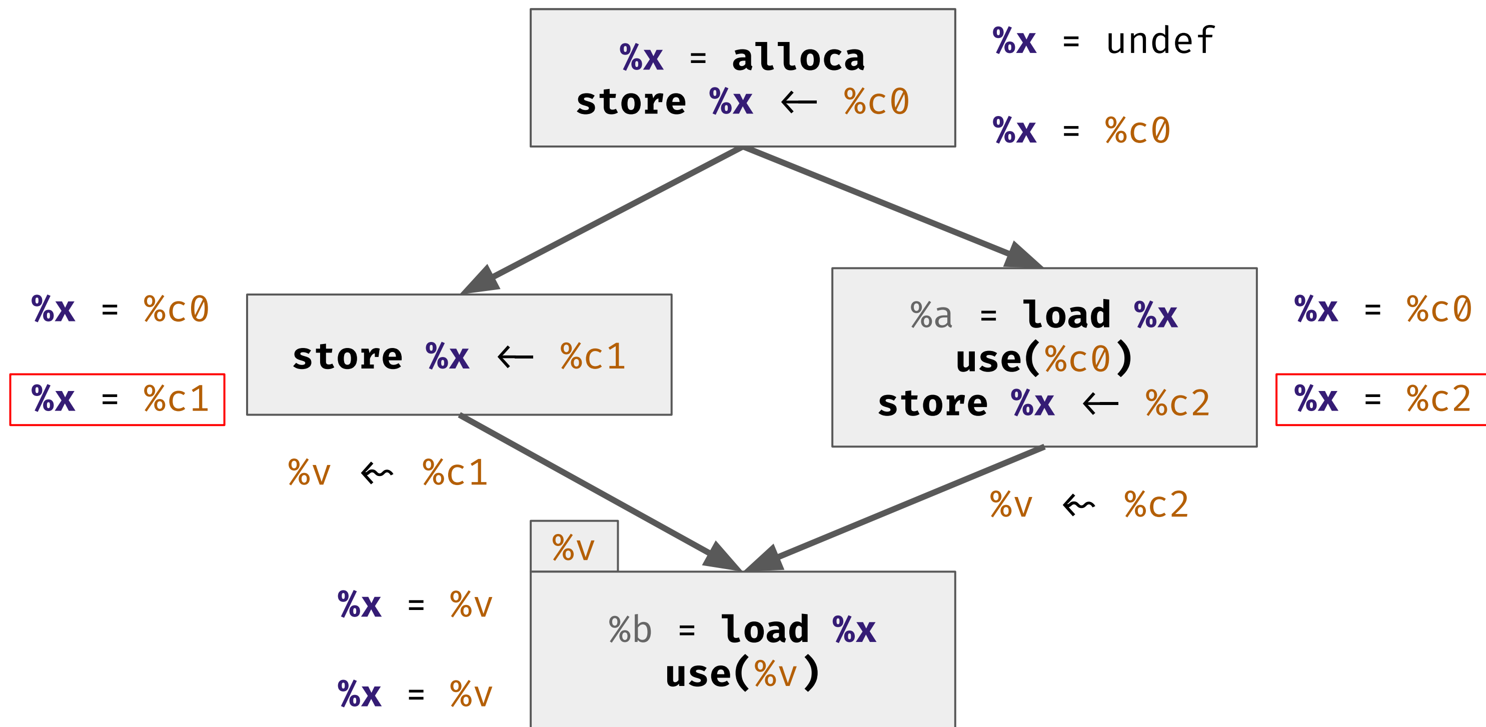

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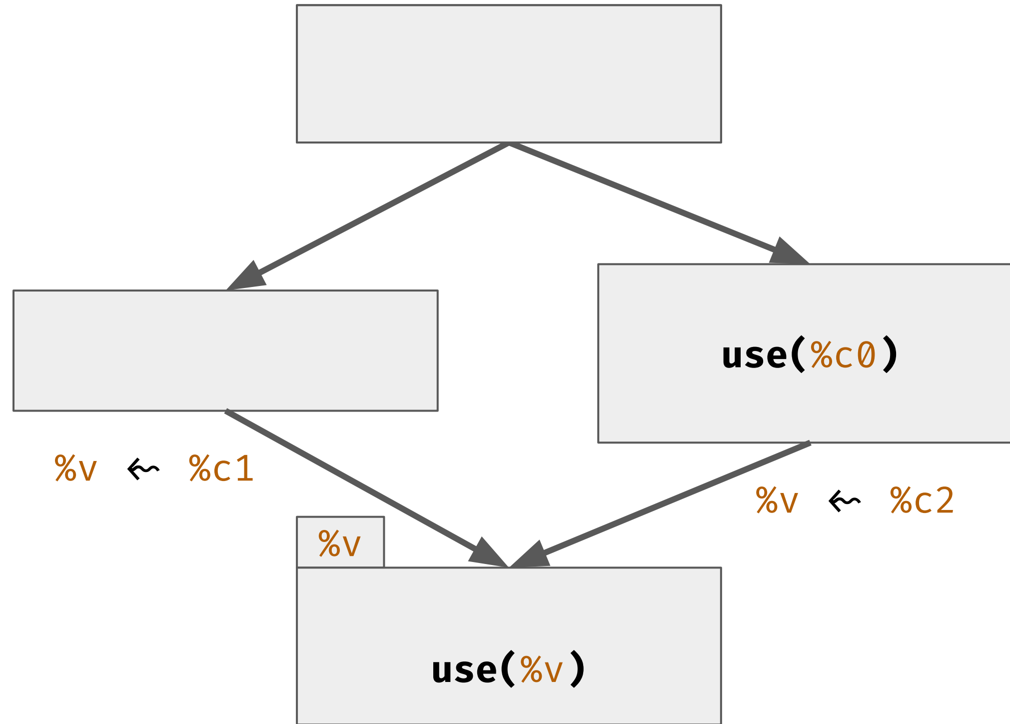

Why Mem2Reg?

- Write programs without caring about SSA
- Remove costly memory usage
- Simplify program structures for analysis and optimization

Mem2Reg in MLIR

- No standard interfaces
- No standard implementation
- Implementation must be done downstream, without coordination

Unfortunate lack of coordination

```
func @demo() -> i32 {
    %const = arith.constant 12 : i32
    %mem = memref.alloca() : memref<i32>

    memref.store %const, %mem : memref<i32>
    %l = memref.load %mem : memref<i32>

    return %l : i32
}
```

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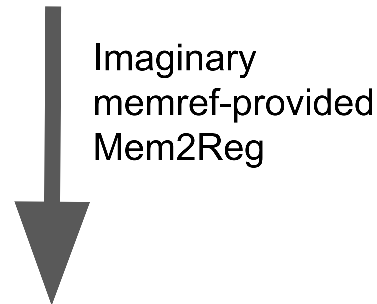


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func @demo() -> i32 {
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```
func @demo() -> i32 {
    %const = arith.constant 12 : i32
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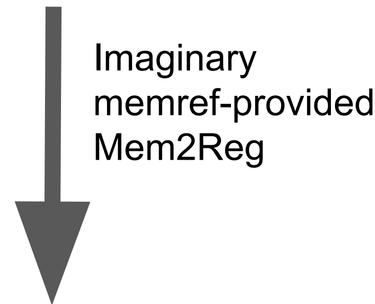

?

Interfaces are well suited!

- Operate on any dialect that *behaves in some specified way*

- No need to define it in advance

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How does one encode Mem2Reg semantics in interfaces?

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Location must be considered in a void

MemorySlot

```
struct MemorySlot {
  /// Pointer to the memory slot.
  Value ptr;
  /// Type of the value contained in the slot.
  Type elemType;
};
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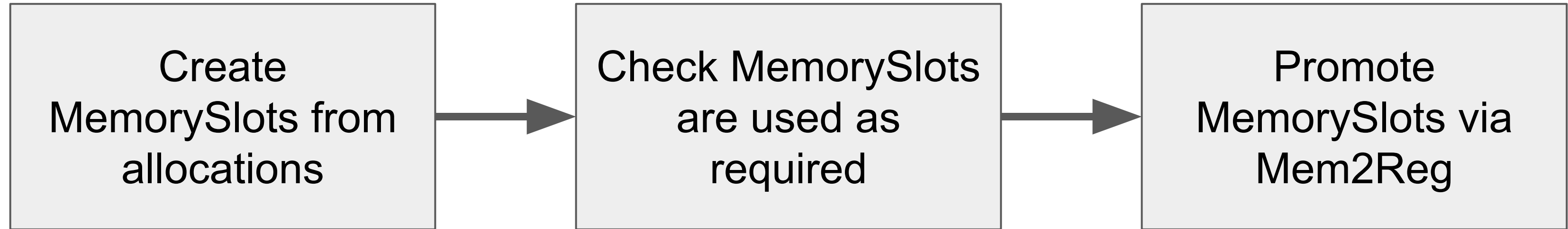
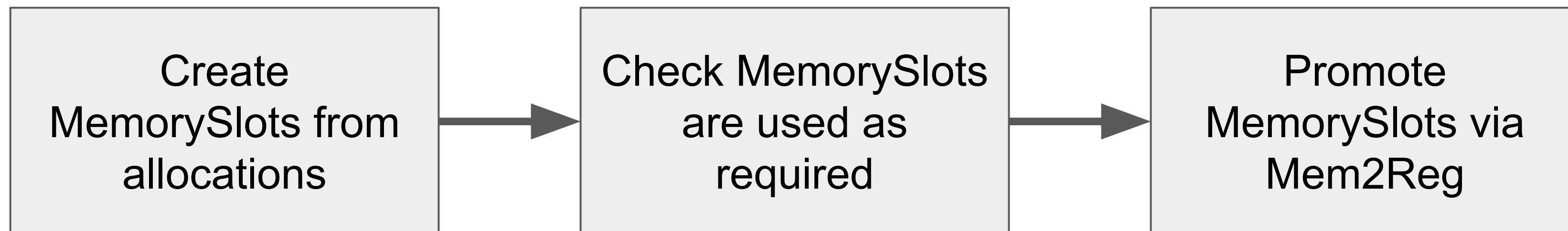
Contains a single value of a given consistent type without aliasing

Pointer must be used to lookup a value of the type and nothing else

MemorySlot



MemorySlot



Let’s implement this for the previous example!

Create MemorySlots

```
func @demo() -> i32 {
    %const = arith.constant 12 : i32
    %mem = memref.alloca() : memref<i32>

    atomic_memref.astore %const, %mem : memref<i32>
    %l = memref.load %mem : memref<i32>

    atomic_memref.metadata %mem : memref<i32>
    return %l : i32
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```

Create MemorySlots from allocations

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Create MemorySlots from allocations

Create MemorySlots

PromotableAllocationOpInterface for `memref.alloca`

```
SmallVec<MemorySlot> getPromotableSlots();

Value getDefaultValue(MemorySlot &slot,
                      RewriterBase &rewriter);

// …
```

Create MemorySlots from allocations

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PromotableAllocationOpInterface for `memref.alloca`

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SmallVec<MemorySlot> getPromotableSlots();

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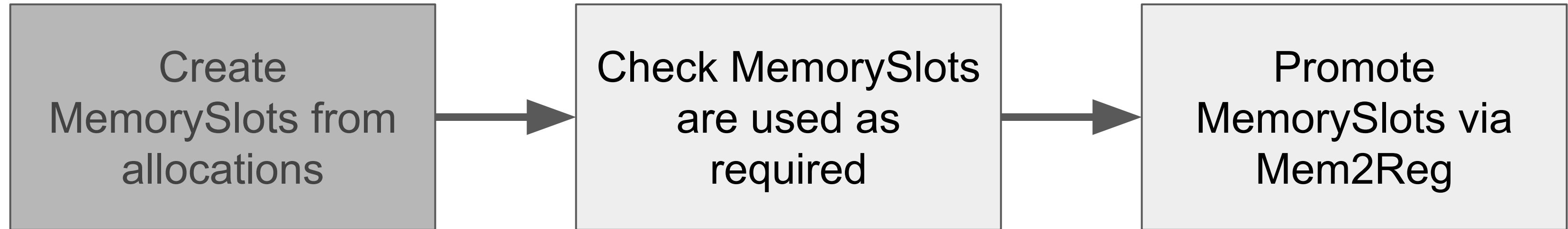
// …
```

```
%mem = memref.alloca() : memref<i32>
```

```
MemorySlot {
  .ptr = %mem,
  .elemType = i32;
};
```

Create MemorySlots from allocations

MemorySlot



Check usage

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“blocking” uses

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Check MemorySlots are used as required

Check usage

PromotableOpInterface for `atomic_memref.metadata`

```
bool canUsesBeRemoved(const Set<OpOperand *> &blockingUses,
                      Set<OpOperand *> &newBlockingUses);

DeletionKind removeBlockingUses(const Set<OpOperand *> &blockingUses,
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- Can uses be removed? Always.
- How to remove them?
  We can just delete the op by returning
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```

Check MemorySlots are used as required

Check usage

PromotableMemOpInterface for `atomic_memref.astore`

```
bool canUsesBeRemoved(const MemorySlot &slot,
                      const Set<OpOperand *> &blockingUses,
                      Set<OpOperand *> &newBlockingUses);

DeletionKind removeBlockingUses(const MemorySlot &slot,
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```

- Can uses be removed? As long as the types are consistent.
- How to remove them?
  We can just delete the op by returning
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Check MemorySlots are used as required

Check usage

PromotableMemOpInterface for `memref.load`

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bool canUsesBeRemoved(const MemorySlot &slot,
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```
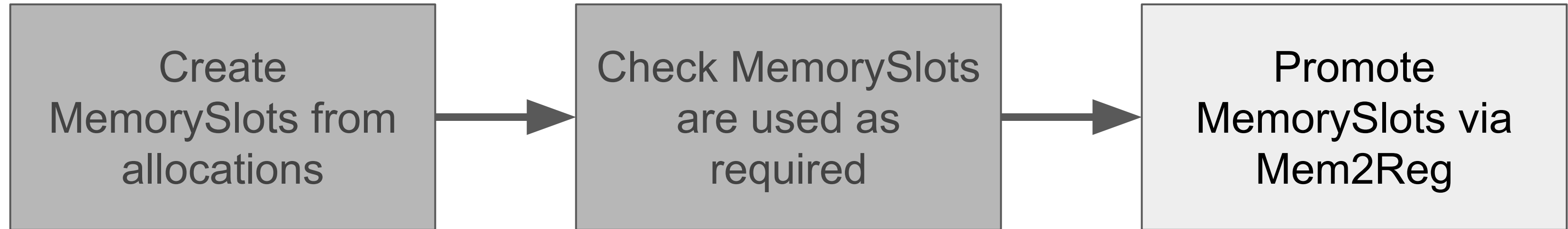

- Can uses be removed? As long as the types are consistent.
- How to remove them?
  We need to replace uses then return
  `DeletionKind::Delete`

Check MemorySlots are used as required

MemorySlot



Analyze behavior for promotion

```
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    atomic_memref.astore %const, %mem : memref<i32>
    %l = memref.load %mem : memref<i32>

    atomic_memref.metadata %mem : memref<i32>
    return %l : i32
}
```

Promote MemorySlots via Mem2Reg

Analyze behavior for promotion

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}
```

Promote MemorySlots via Mem2Reg

Analyze behavior for promotion

PromotableMemOpInterface

```
bool loadsFrom(const MemorySlot &slot);

bool storesTo(const MemorySlot &slot);

Value getStored(const MemorySlot &slot,
                RewriterBase &rewriter);
```

Promote MemorySlots via Mem2Reg

Analyze behavior for promotion

PromotableMemOpInterface

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bool loadsFrom(const MemorySlot &slot);

bool storesTo(const MemorySlot &slot);

Value getStored(const MemorySlot &slot,
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```

We can now apply the Mem2Reg rewrite pattern!

Promote MemorySlots via Mem2Reg

Mem2Reg for any dialect

- Interfaces to define how operations interact with Mem2Reg
- Upstream rewrite pattern or pass to apply the transformation
- Out-of-the-box coordination between dialects

Basic SROA also available

- Allows breaking aggregate-like types into their fields

- Achieved by breaking allocators of large MemorySlots into allocators of their fields

- Interfaces to prove slots are used correctly
  - `DestructurableAllocationOpInterface`
  - `SafeMemorySlotAccessOpInterface`
  - `DestructurableAccessorOpInterface`

What implementations are currently upstream

LLVM Dialect

- Support for `alloca` stack slots
- Support for debuginfo and markers
- Support for memory intrinsics
- Basic SROA on structs and arrays

MemRef Dialect

- Support for MemRef `alloca`
- Support for Mem2Reg of scalar MemRefs
- Basic SROA of small higher rank MemRefs

Still lots of things to be done!

- More interface design needed to support structured control flow
- Terminators must be branch-like control-flow
- More public support for open dialects that need it

Thank you!