An Introduction to MEMOIR

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Advanced Topics in Compilers

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ARCANA
Rethinks Compiler Abstractions for New Applications

CONSTELLATION PROJECT

m&moir

Overview

Bird's Eye View

MEMOIR is a

Bird's Eye View

MEMOIR is a

Compiler Intermediate Representation

Bird's Eye View

MEMOIR is a

Compiler Intermediate Representation

for

Data Collections and Objects

Bird's Eye View

MEMOIR is a

Compiler Intermediate Representation

for

Data Collections and Objects

in an

SSA Form

Outline

What is a Data Collection?

Outline

What is a Data Collection?

What is SSA?

Outline

What is a Data Collection?

What is SSA?

How can I analyze it?

Outline

What is a Data Collection?

What is SSA?

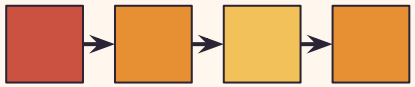
How can I analyze it?

How can I transform it?

Data Collection

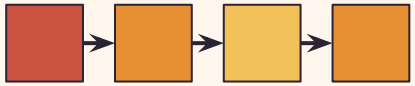
A logical organization of data

Examples



List

Examples



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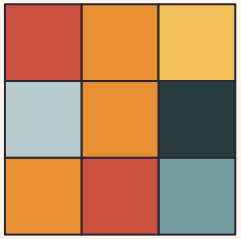
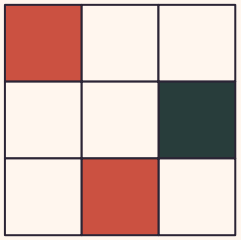
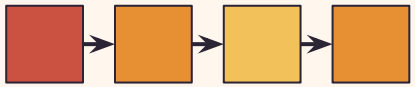


Dense Array



Sparse Array

Examples



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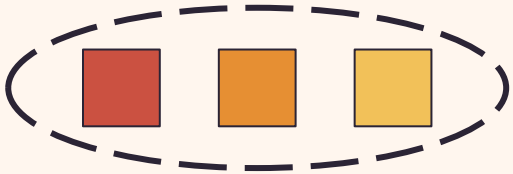
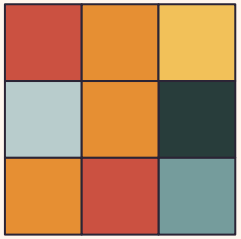


Set



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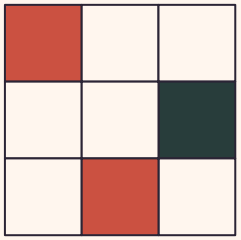
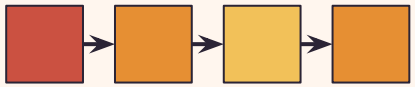


Sparse Array

Examples



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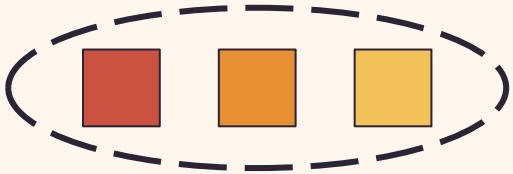

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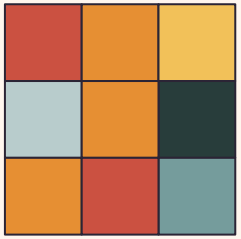

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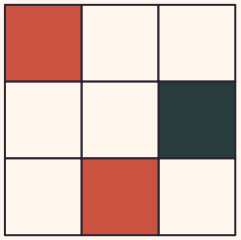

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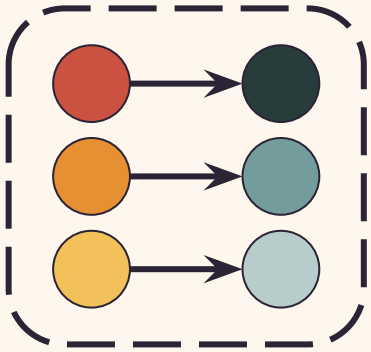
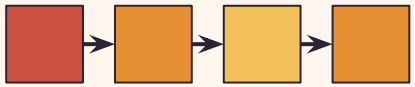


Map

Examples



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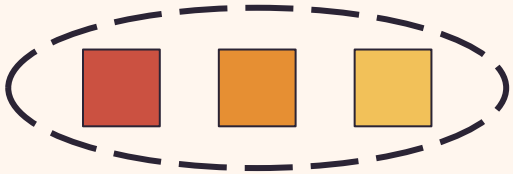

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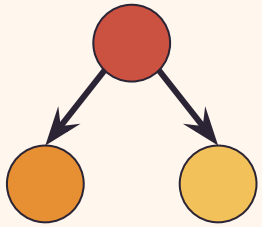
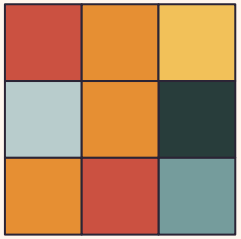


Tree



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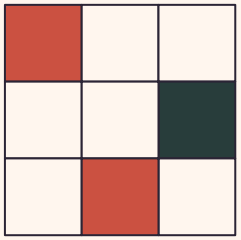

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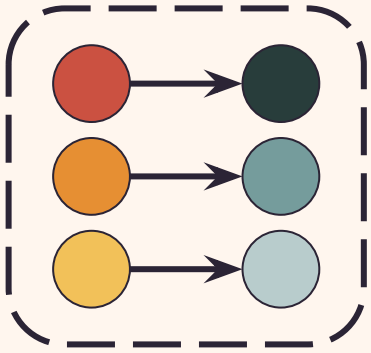

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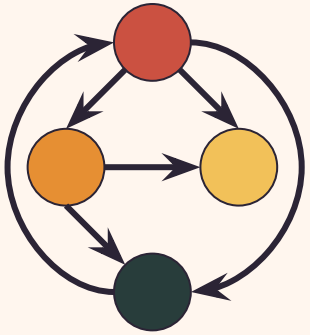
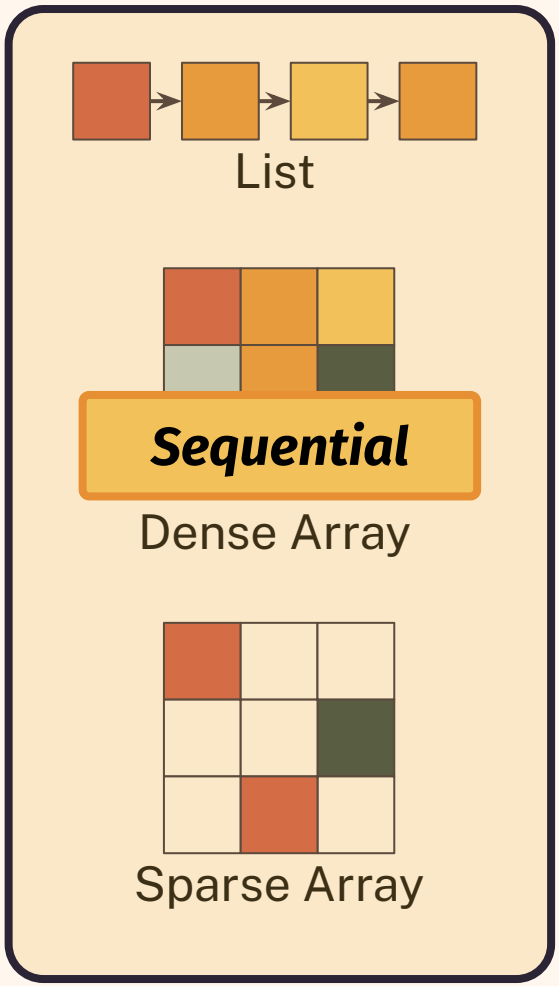
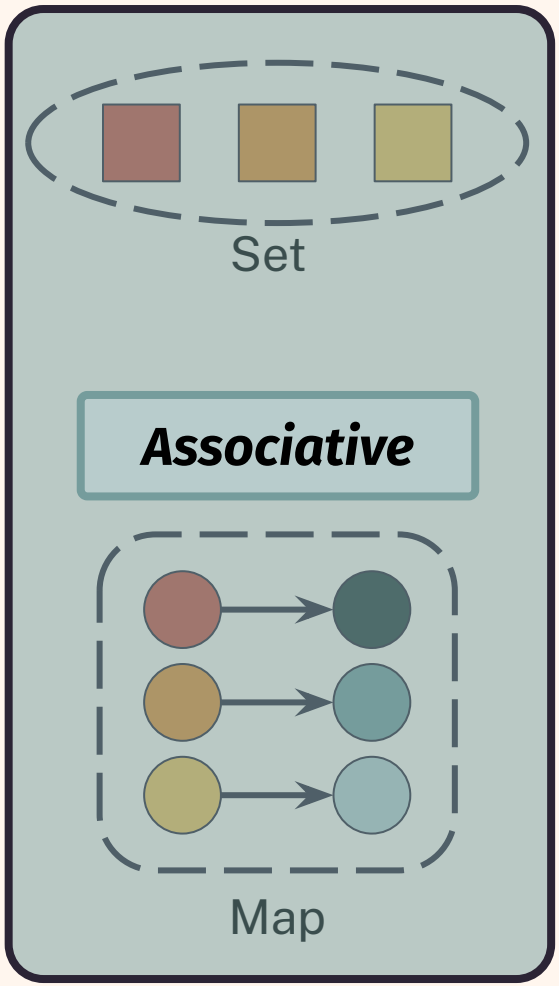
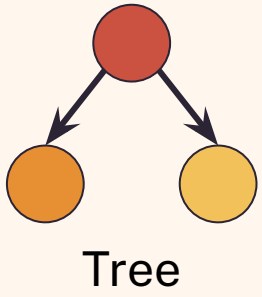


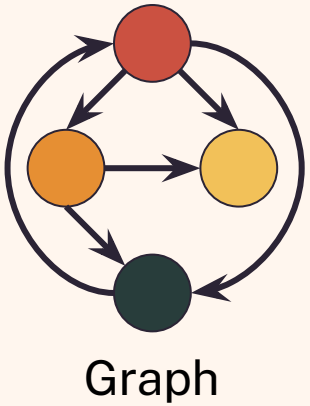
Graph

Examples

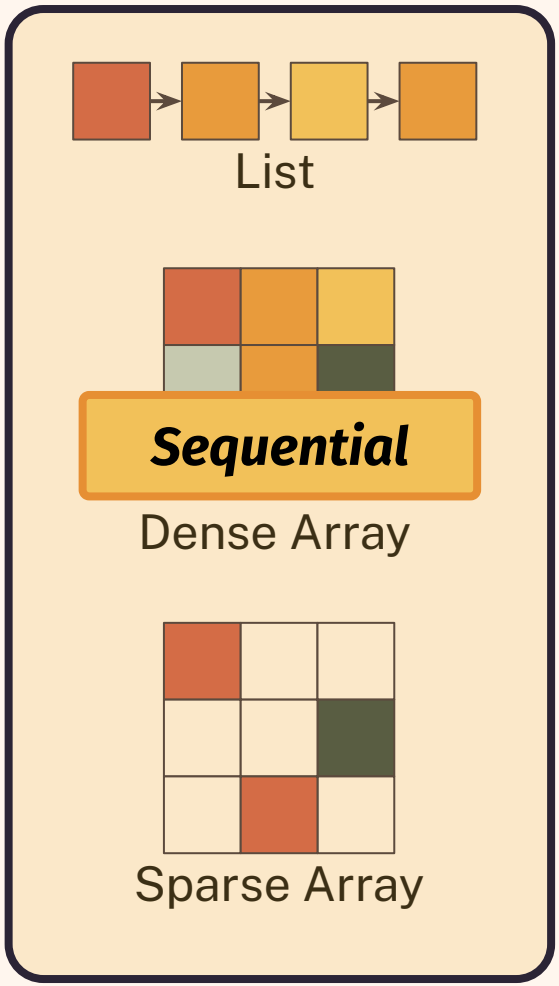

List
Sequential
Dense Array
Sparse Array


Set
Associative
Map


Tree


Graph

Examples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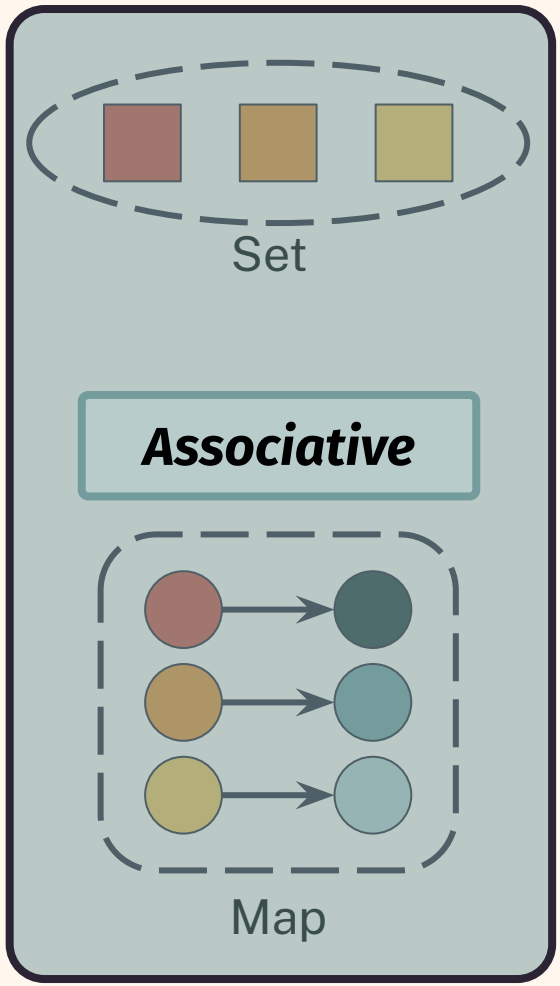
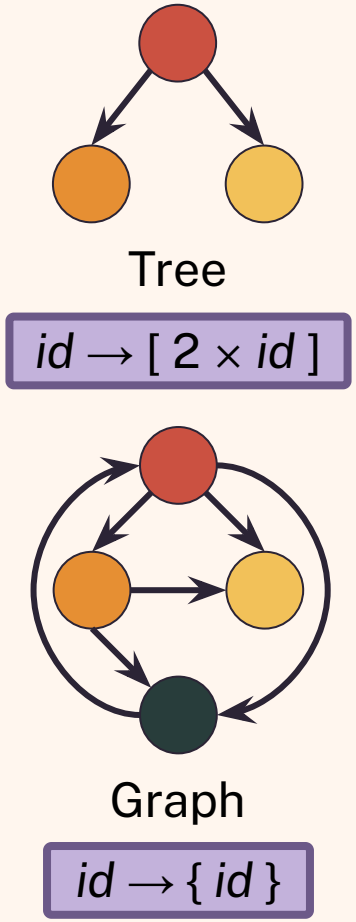
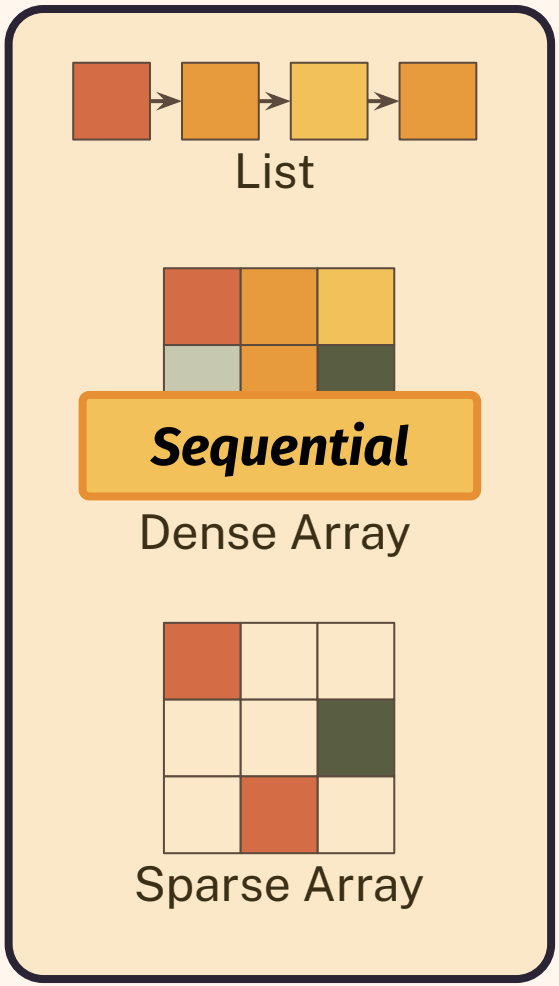

Set
Associative
Map


Tree
$id \rightarrow [\ 2 \times id\ ]$
Graph
$id \rightarrow \{\ id\ \}$

Examples


List
Sequential
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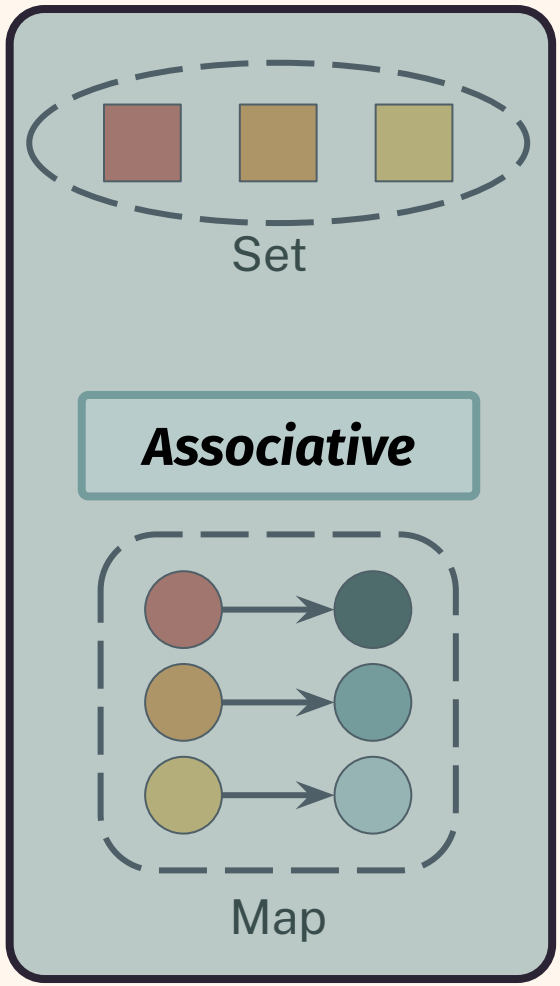
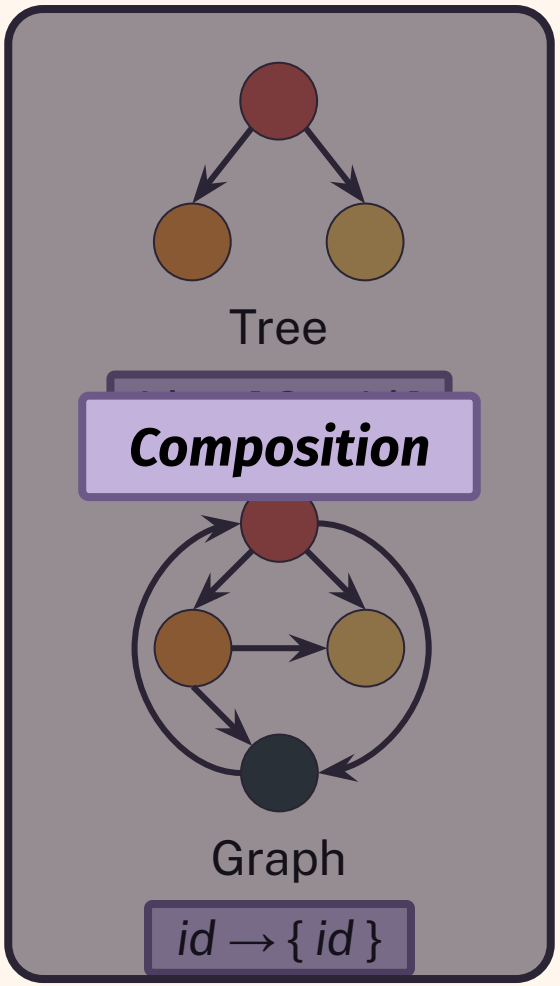
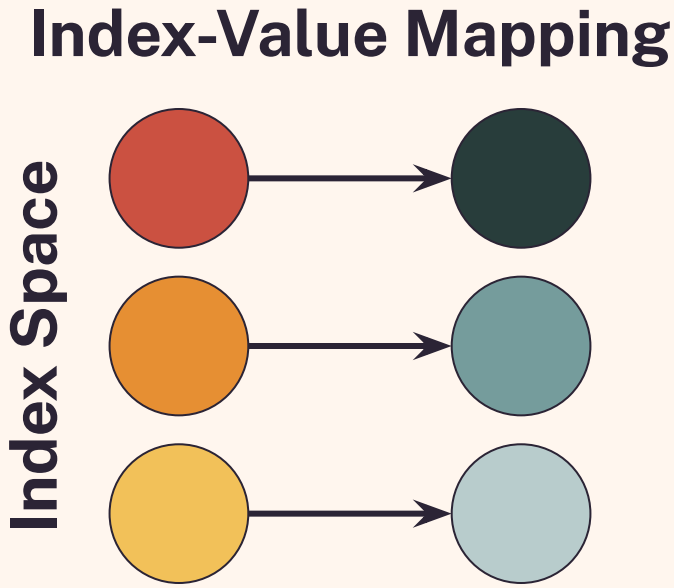
Sparse Array

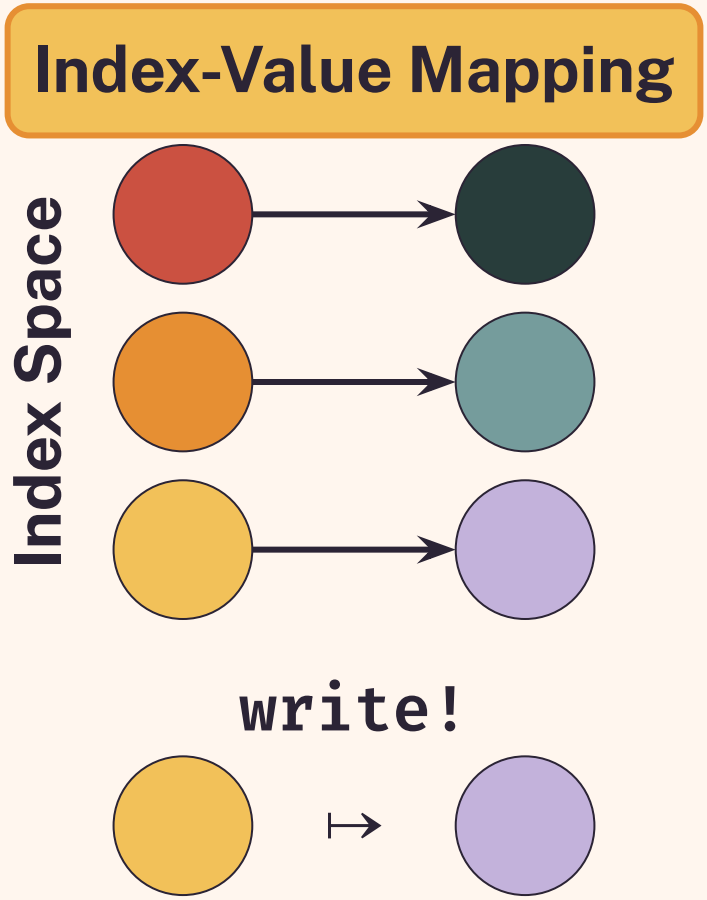

Set
Associative
Map


Tree
Composition
Graph
id → { id }

Representation



Operations on the *Index-Value Mapping*



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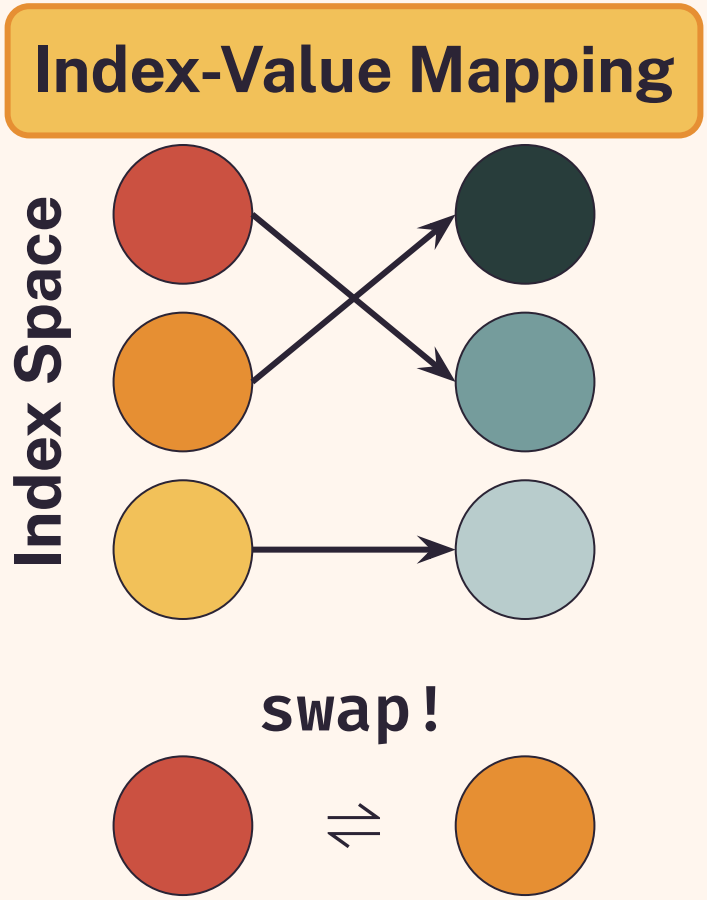
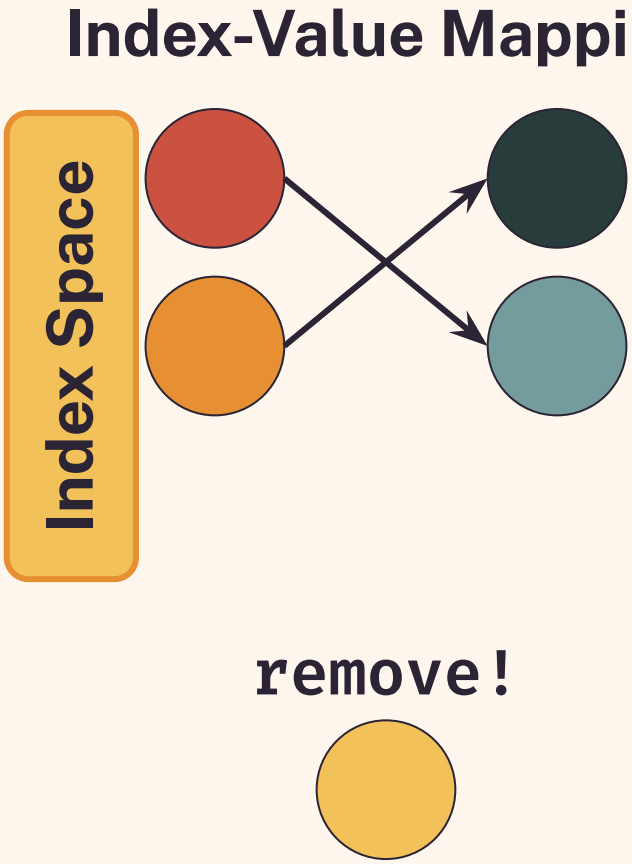
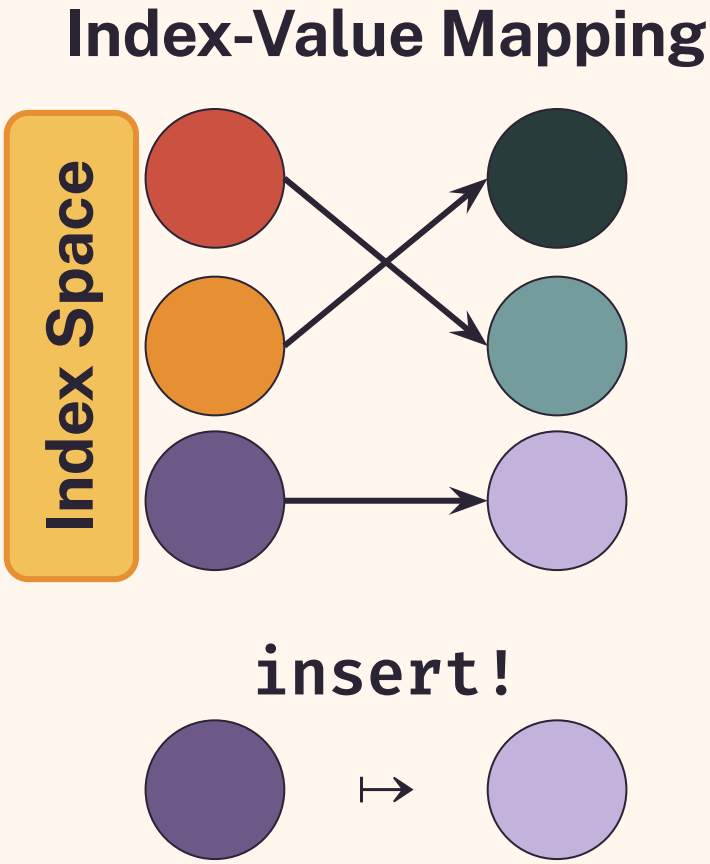


Operations on the *Index Space*



Operations on the *Index Space*



Static Single Assignment

A language constraint, where *each variable* has a *single definition* in the static program.

Why SSA?

↓

Referential Transparency

Referential Transparency

Replacing a *subexpression* with an *equivalent one* produces an *equivalent expression*.

Referential Transparency

She lives in Chicago

$\asymp$

She lives in the largest city in Illinois

Referential Opacity

‘*Chicago*’ contains seven letters

$\not\asymp$

‘*The largest city in Illinois*’ contains seven letters

Benefits of Referential Transparency

A variable's value is ***independent of its position in the program***

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A variable's value is ***independent of its position in the program***

Information attached to the ***definition of a variable*** is true for ***all uses of the variable***

So, what about data collections?

```
write!(c, i, v)
```

Semantics: Following this operation, `c[i] = v`

So, what about data collections?

`write!(c, i, v)`

Semantics: Following this operation, `c[i] = v`

But, is `read(c, i)` $\asymp$ `v`?

Not necessarily! Depends on its position in the program.

So, what about data collections?

```
write!(c, i, v)
```

```
read(c, i)
```

Yep! The use of **`c`** is dominated by the **`write!`** and is not dominated by any other **`write!`** to **`c`**

So, what about data collections?

```
write!(c, i, v)

write!(c, i, w)

read(c, i)
```

Nope! The use of **`c`** is dominated by the **`write!`**, but is dominated by another **`write!`** to **`c`**

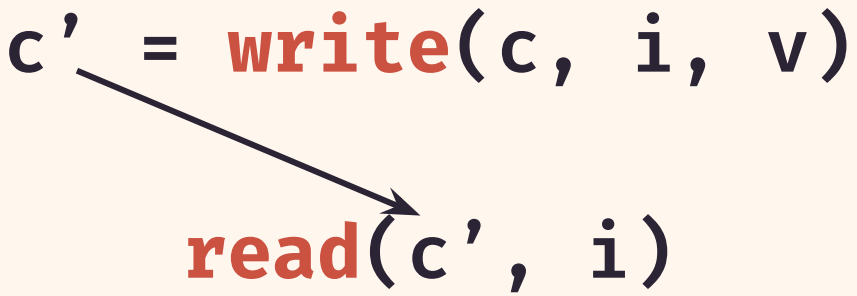
So, what about data collections?

```
read(c, i)
```

```
write!(c, i, v)
```

Nope! The use of **`c`** is not dominated by the **`write!`**

So, how do we fix this? SSA Construction.



So, what about MEMOIR?

Each operation on a collection produces a new collection

(except for `read`)

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write!(c, i, v)    → c' = write(c, i, v)
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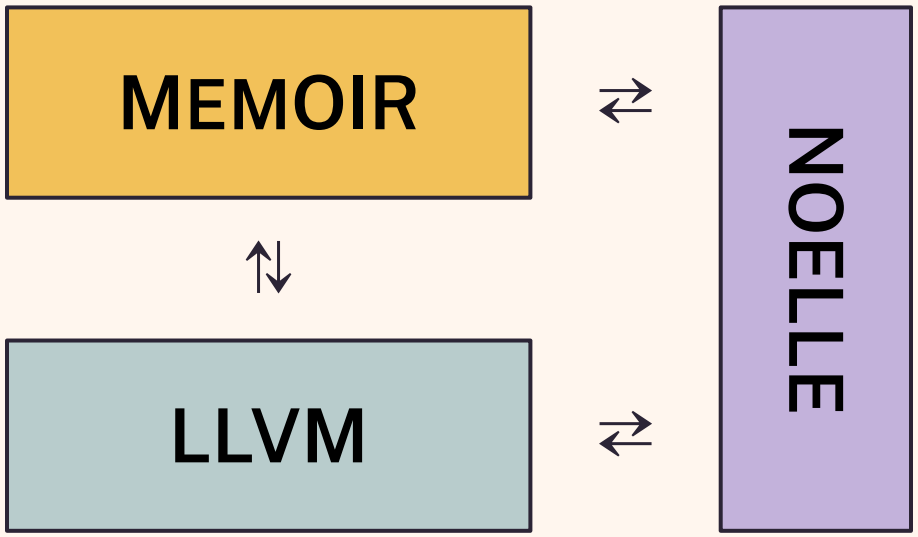
remove!(c, i)       → c' = remove(c, i)
insert!(c, i, v)    → c' = insert(c, i, v)
read(c, i)          → v  = read(c, i)
```

So, what about MEMOIR?

Other, useful query operations can be easily performed:

```
n = size(c)     ▷ # of elements in c
h = has(c, i)   ▷ does c have index i?
ks = keys(c)    ▷ sequence of keys in c
```

The MEMOIR Compiler



Step-by-step instructions are available

Writing a pass:

mcmichen.cc/memoir-docs/user/writing_a_pass

Writing a program:

mcmichen.cc/memoir-docs/user/writing_a_program

Additional Resources

Developer manual:

mcmichen.cc/memoir-docs

Doxygen:

mcmichen.cc/memoir-doxygen

The CGO'24 paper:

mcmichen.cc/files/MEMOIR_CGO_2024.pdf

Yippee!

Live Coding Time