Capable: Capabilities for Scalability

Current state of design

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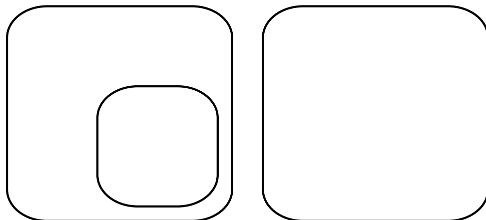
Introduction

- Safe parallel programming using capabilities
- Scalability and performance rather than verification

Background

- Ownership types prescribe structure



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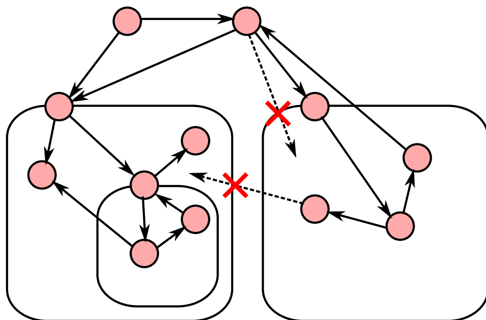

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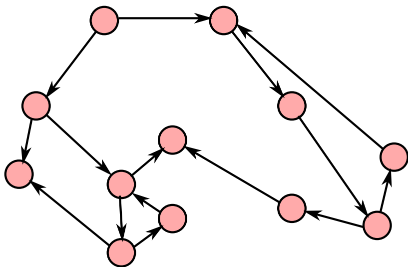
- Ownership types prescribe structure
- Effect systems describe usage



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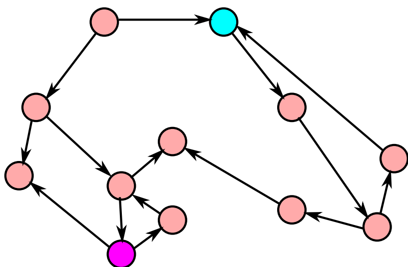

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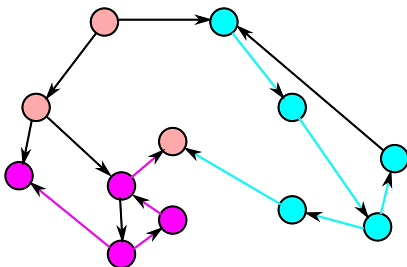

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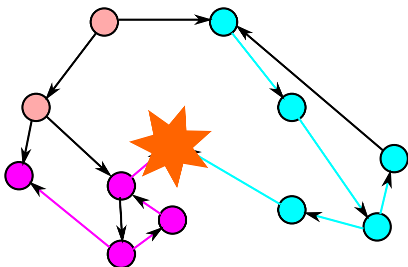
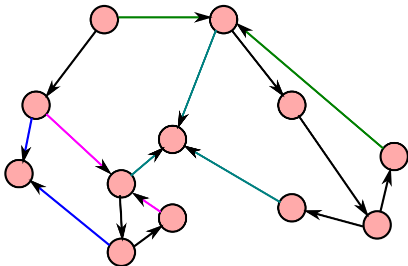


Background

- Ownership types prescribe structure
- Effect systems describe usage
- We're aiming somewhere in-between:

  Any structure is allowed as long as all aliases are non-interfering.



Outline

- Introduction
- Background
- Capabilities
- Traits and classes
- Composition, splitting and merging
- Nesting and parametricity
- Composition as abstract memory layout specification

Capabilities

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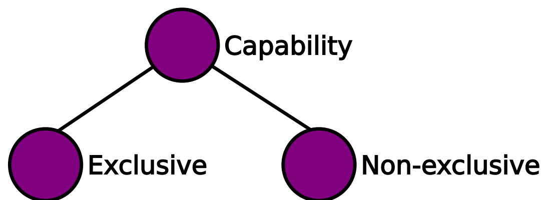

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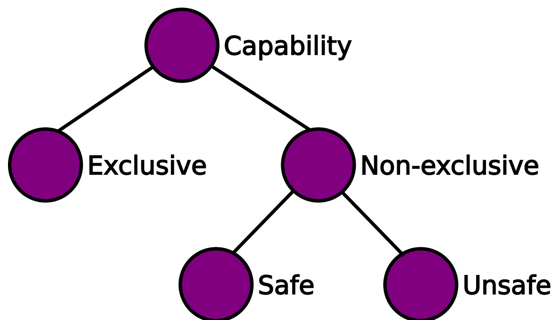

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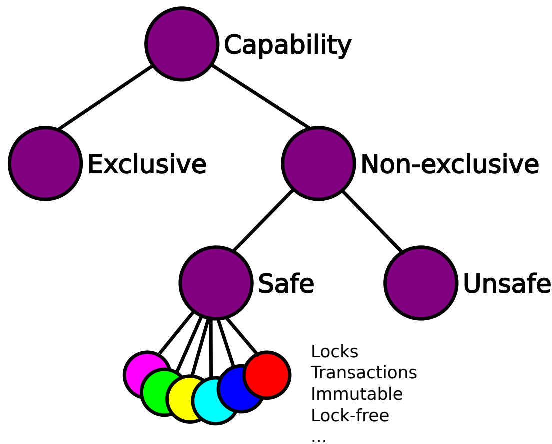

Safety

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- Baseline:
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  - Exclusive capabilities are (and remain) exclusive
- Our focus: Lock-free capabilities with static support for speculation and publication of values (see paper for more details)

Traits

- Capabilities are introduced using traits:

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  require int value;
  int get(){
    return this.value;
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safe trait Get{
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- Traits are exclusive by default:

```
trait Set{
  require int value;
  void set(int val){
    this.value = val;
  }
}
```

Classes

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trait Set{
  require int value;
  void set(int val)...
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safe trait Get{
  require int value;
  int get()...
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- Classes are formed by composing traits:

```
class Cell = Set ⊕ Get*{
  provide int value;
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- Classes are formed by composing traits:

```
class Cell = Set ⊕ Get*{
  provide int value;
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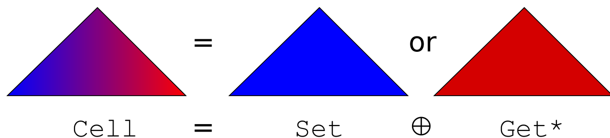
```

- Class types are composite capabilities:

```
Cell c = new Cell;
c.set(42);
c.get();   // = 42
```

Composition and splitting

- A *disjunction* can be split into *either* of its components:



Composition and splitting (`Cell = Set ⊕ Get*`)

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x = new Cell;
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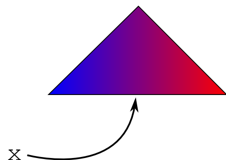

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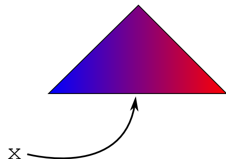

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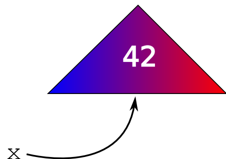

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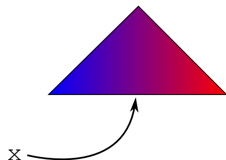


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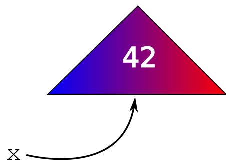


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x = (Get*) consume x;
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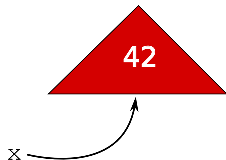

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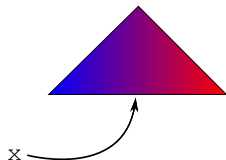


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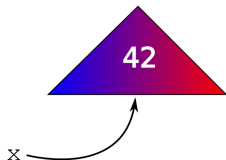


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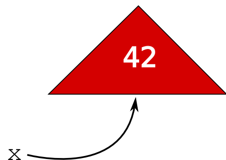

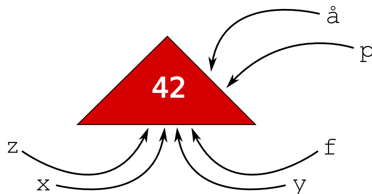

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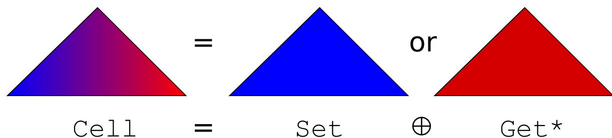

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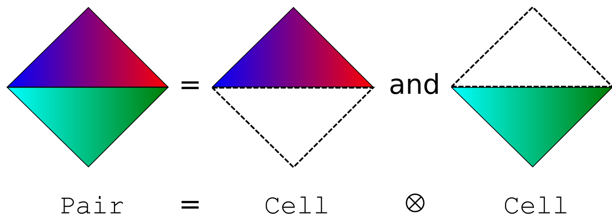

Composition and splitting (Pair = Cell ⊗ Cell)

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p = new Pair;
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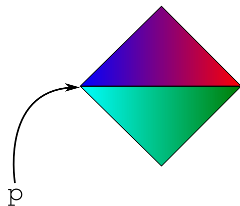

Composition and splitting (`Pair = Cell` $\otimes$ `Cell`)

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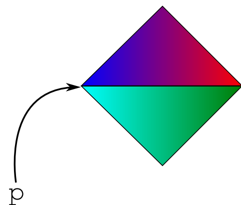


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Cell c1, c2 = consume p;
```

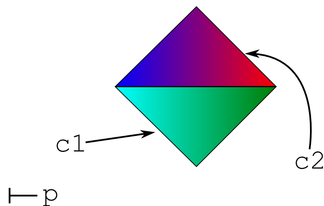

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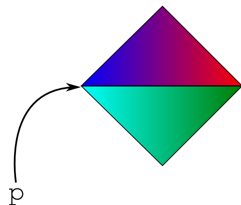


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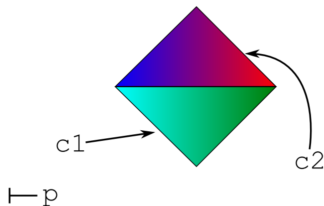
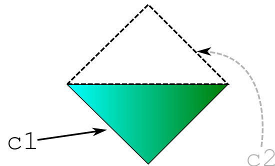


`c1` and `c2` are aliases, but can only access "their half" of the `Pair`:



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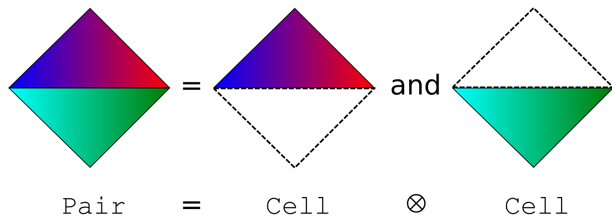

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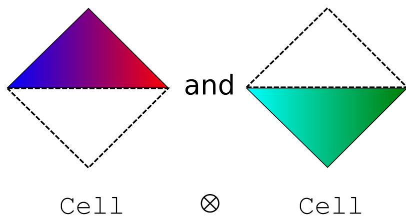

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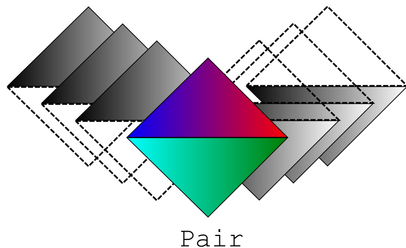

Merging

- Structured split and merge

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Pair p = ...;
split p into Cell c1, c2 in{
  ...  // p is invalidated
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p = consume c1 ⊗ consume c2
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Pair p = ...;
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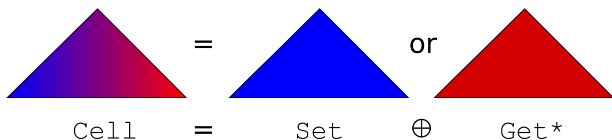
...
p = consume c1 ⊗ consume c2 ← dynamic alias check!
...  // c1 and c2 are invalidated
```

Merging

- What about disjunction?



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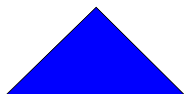

Set

Merging

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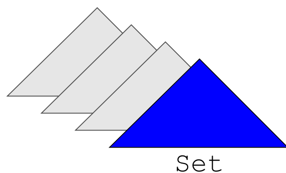

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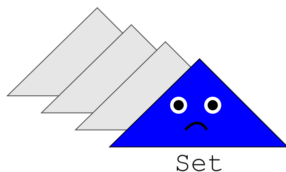
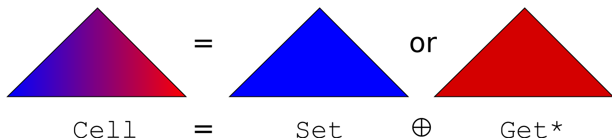


- The `Get` capability is lost!

Splitting with Jails

- `Cell = Set` $\oplus$ `Get`* means `Set` and `Get`* may not be used in parallel



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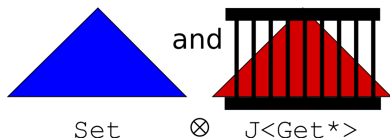

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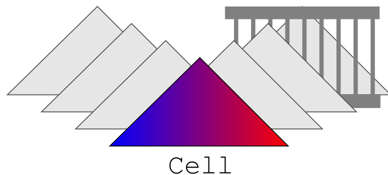

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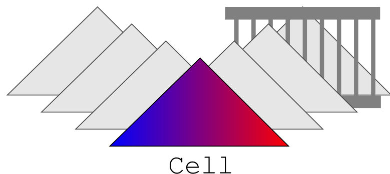

- A *jailed* capability is an alias with an empty interface
- Jails can turn any disjunction $\mathtt{c}_1 \oplus \mathtt{c}_2$ into a conjunction $\mathtt{c}_1 \otimes \mathtt{J}\langle\mathtt{c}_2\rangle$, which can be split and merged in a non-lossy way

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- Capabilities are either *exclusive*, *safe* or *unsafe*
- *Traits* specify behaviour and introduce capability types.
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  - A *conjunction* $c_1 \otimes c_2$ can be split into *both* c_1 and c_2 which may be used in parallel
- Merging can be used to regain composite capabilities in both structured and unstructured ways

Co-encapsulation through nesting

- Parametricity exposes internal details about a nested capability

```
class List⟨T⟩ = Add⟨T⟩ ⊕ Del⟨T⟩ ⊕ Nth*⟨T⟩{
  provide Link⟨T⟩ first;
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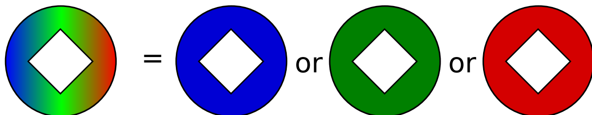

List<T> = Add<T> ⊕ Del<T> ⊕ Nth*<T>

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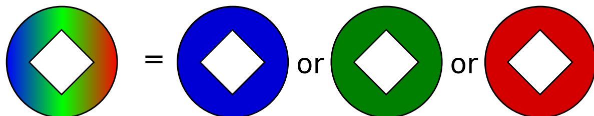
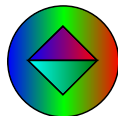
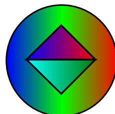




Nesting and splitting

$$\texttt{List}\langle\texttt{T}\rangle = \texttt{Add}\langle\texttt{T}\rangle \oplus \texttt{Del}\langle\texttt{T}\rangle \oplus \texttt{Nth}^{*}\langle\texttt{T}\rangle$$

$$\texttt{Pair} = \texttt{Cell} \otimes \texttt{Cell}$$



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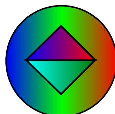
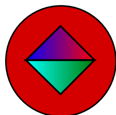


List<Pair>

Outer split:



Nth*<Pair>

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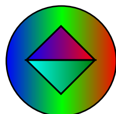
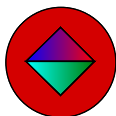


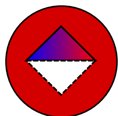
List<Pair>

Outer split:

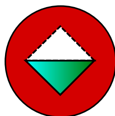


Nth*<Pair>

Inner split:



and



Nth*<Cell> ⊗ Nth*<Cell>

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- Merging non-exclusive capabilities
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- See paper for more details

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Thank you!