關於生命週期的一點事兒

The relationship of Lifetimes and DataFlow

Rnic / H.-S. Zheng

Aug 17, 2019 @ COSCUP

Audience

- 讀過 Rust Book
- 想要了解編譯器怎麼看待 Lifetimes
- 對編譯器有那麼一點興趣
- ~~想要輕鬆駕馭 Rust's Lifetimes~~
- ~~想要快快樂樂寫 Rust~~

Outline

- 1. Introduction
  - Example1
  - Basic Lifetimes Concepts
- 2. Borrow Checker
  - Collaborate with Data Flow
  - Example2
  - Datafrog (a datalog engine used in Polonius)

Compilation of Rust

Rust Code

```
let foo: T = Foo {};
let bar: T = Bar {};

let mut p = &foo;

if cond {
        println!("{}", *p);
        ...
        p = &bar;
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}

println!("{}", *p);
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Compilation of Rust

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HIR

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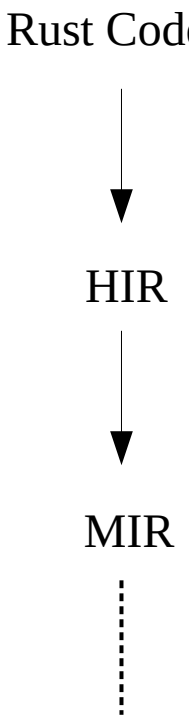


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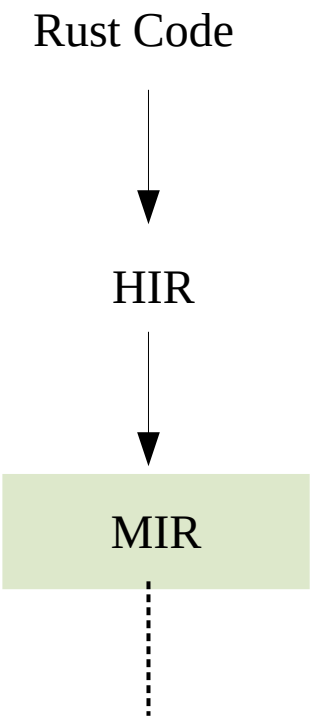


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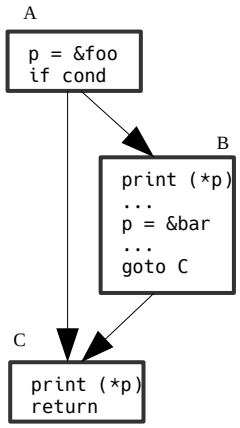

Control Flow Graph

Compilation of Rust

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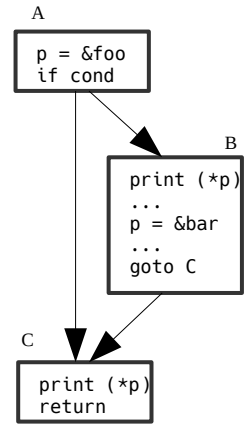

Control Flow Graph

Borrow checker

Theorem: Data Flow Analysis

Tool: Datafrog

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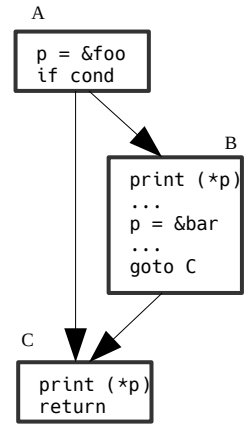

Control Flow Graph

Documents

NLL RFC:
2094-nll

Polonius:
an-alias-based-formulation
-of-the-borrow-checker

Borrow checker

Theorem: Data Flow Analysis

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Example

```
fn list_not(mut head: Option<Box<ListNode>>) -> Option<Box<ListNode>>

{
    let mut cur = &mut head;


    while let Some(nodeBox) = cur.as_mut() {

        nodeBox.val = !nodeBox.val;

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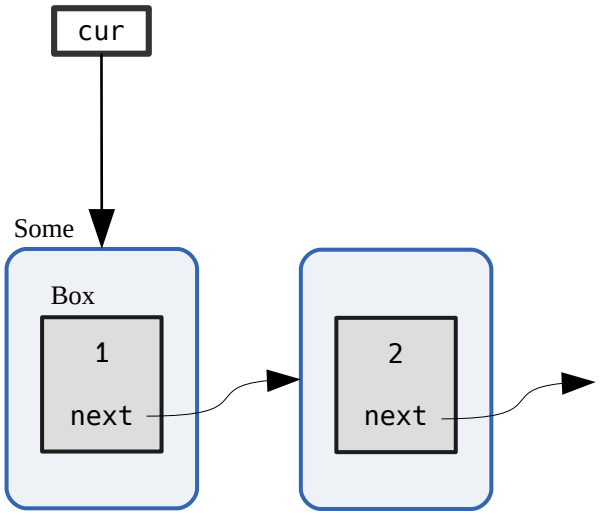

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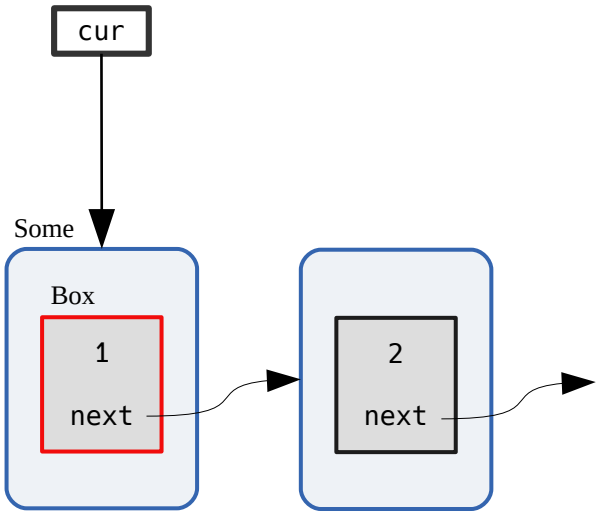

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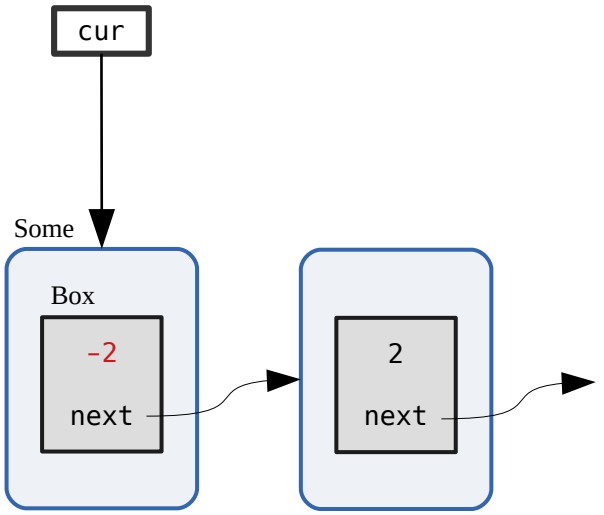

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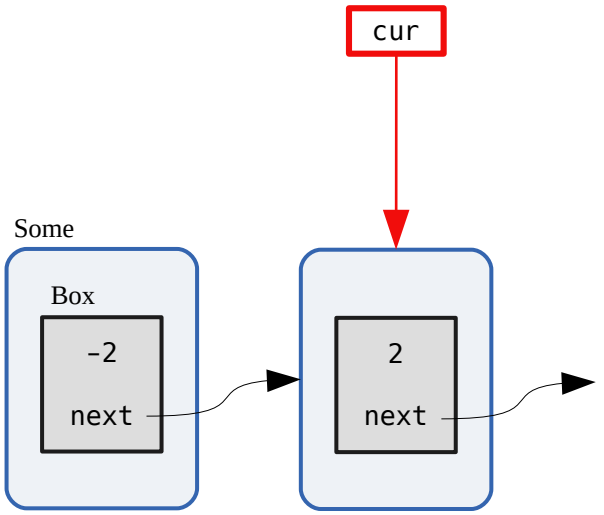

依照使用區間判斷

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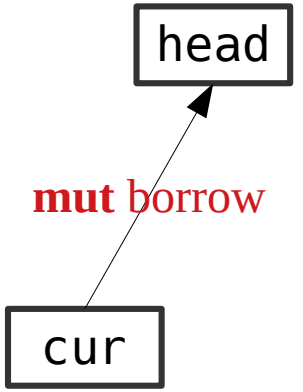

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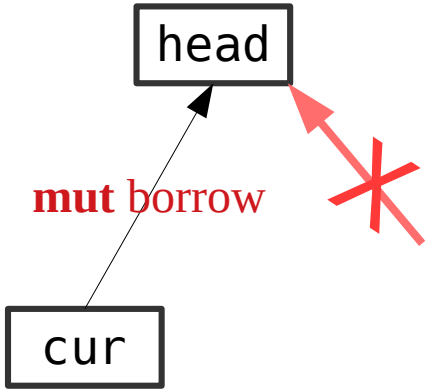

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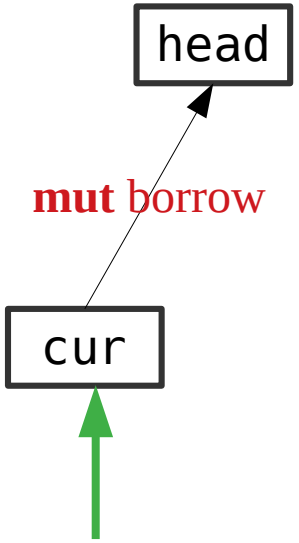

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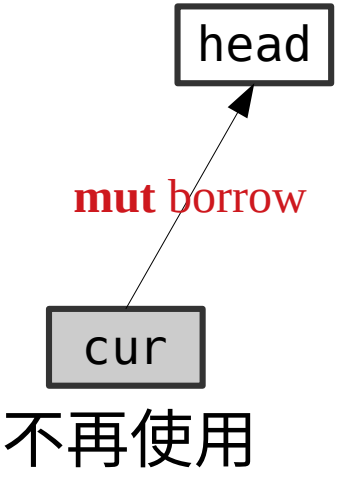

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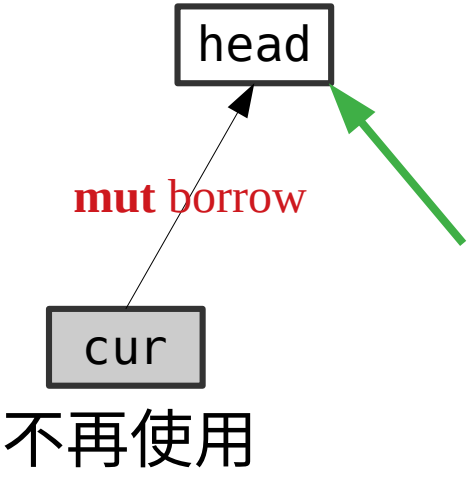

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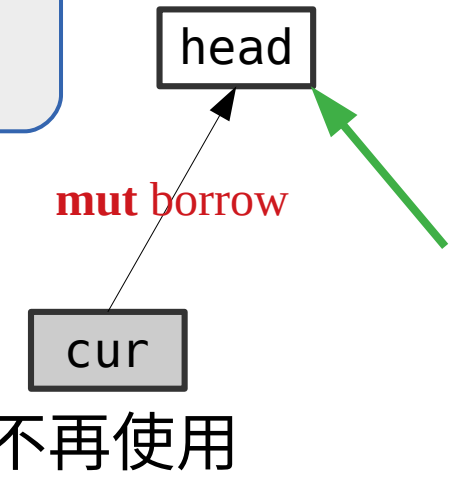
```

`cur' only used here



不再使用

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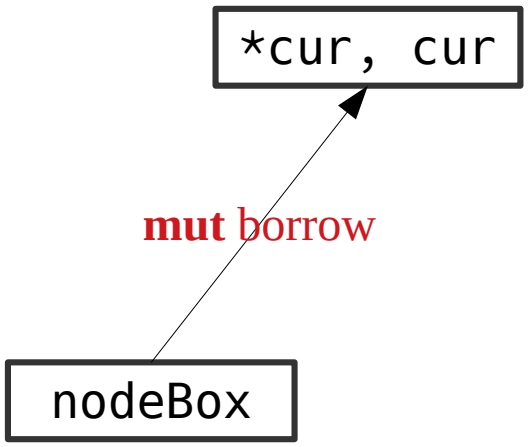

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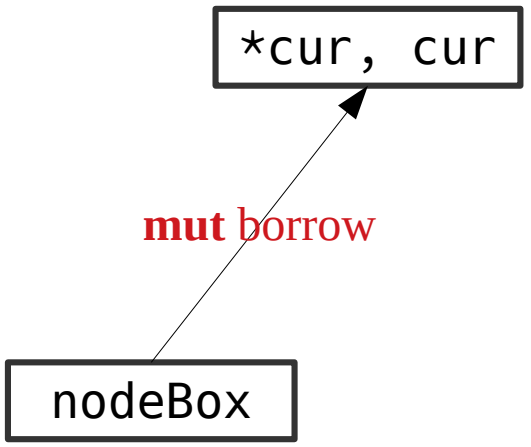

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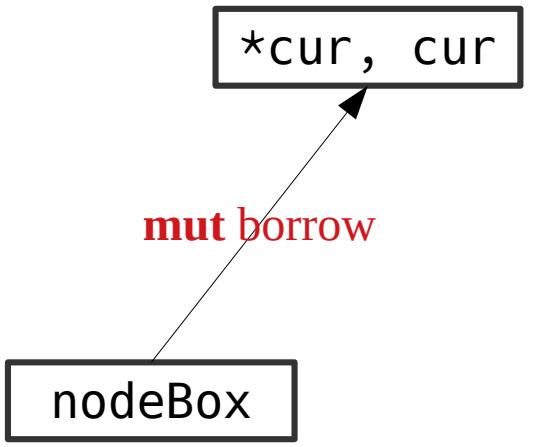


1. **nodeBox** finally used here
2. Assignment to `**cur**' killed the borrow expression

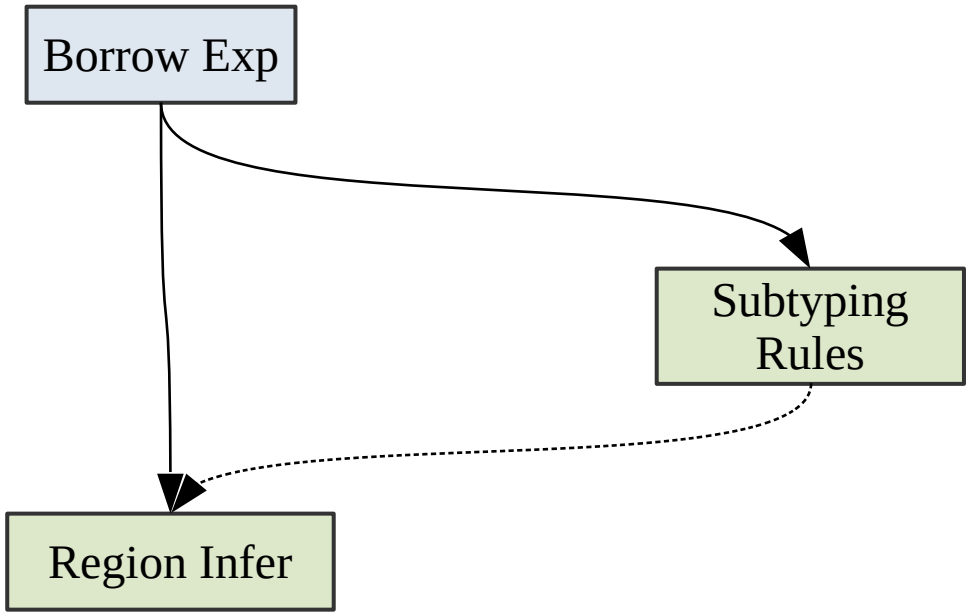
Borrow

P_0 : `let r: &T`
P_1 : `r = &x;`

Borrow Exp

Borrow

```
P0 : let r: &'0 T
P1 : r = &'1 x;
```



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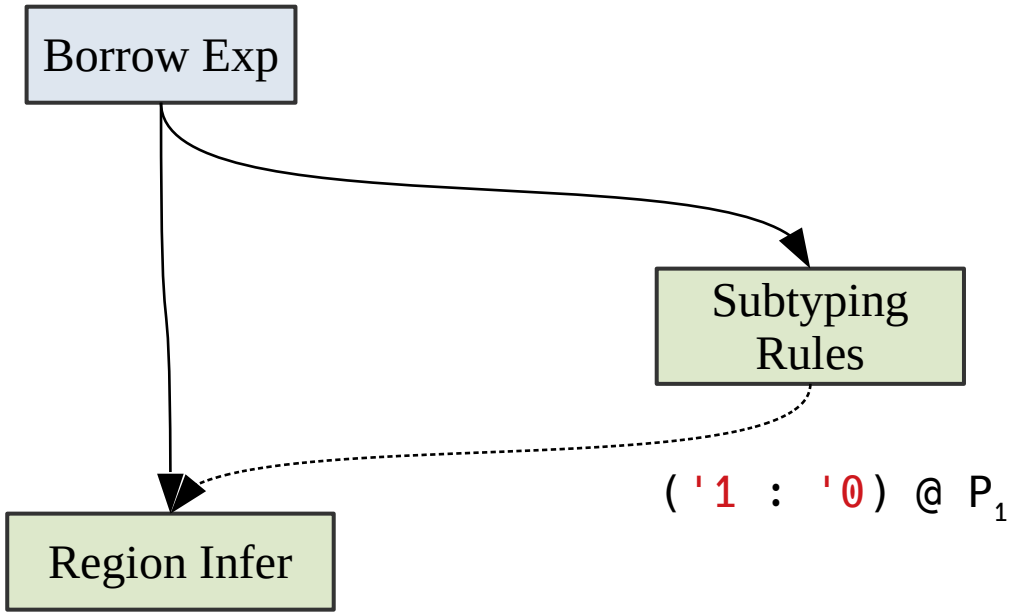
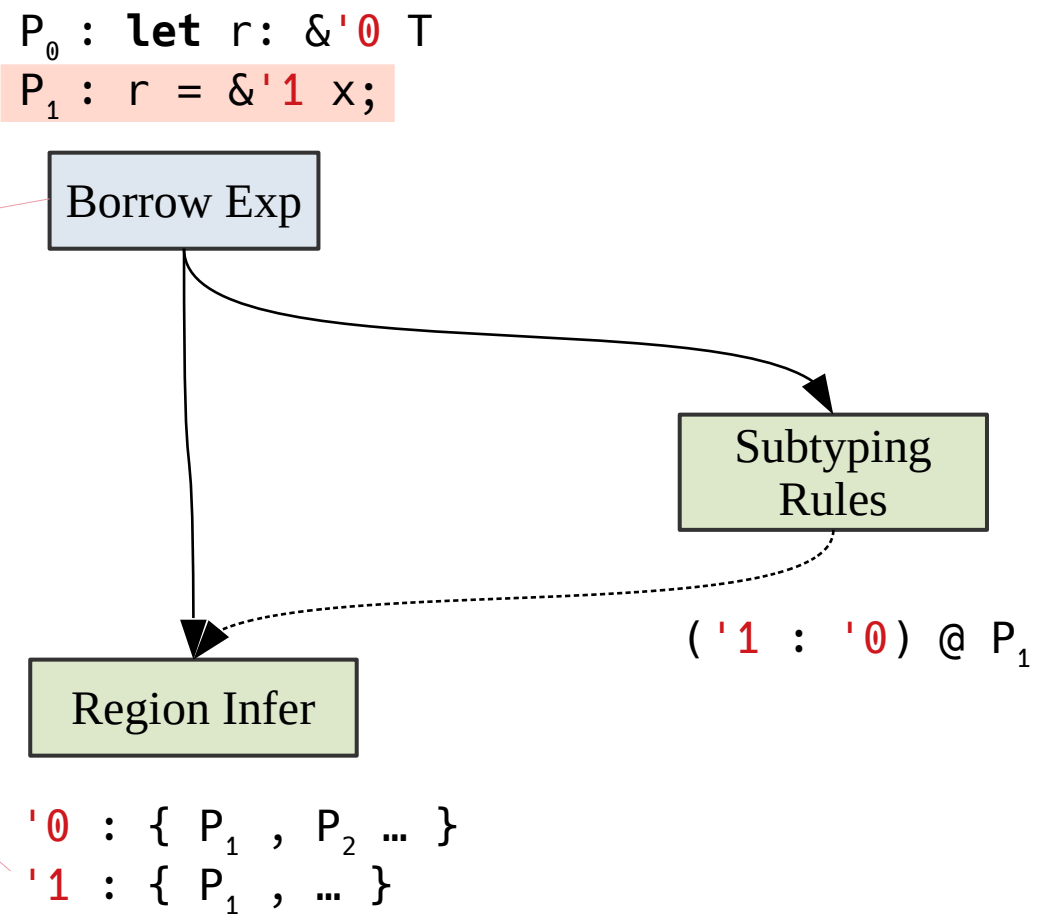



```
'0 : { P1 , P2 … }
'1 : { P1 , … }
```

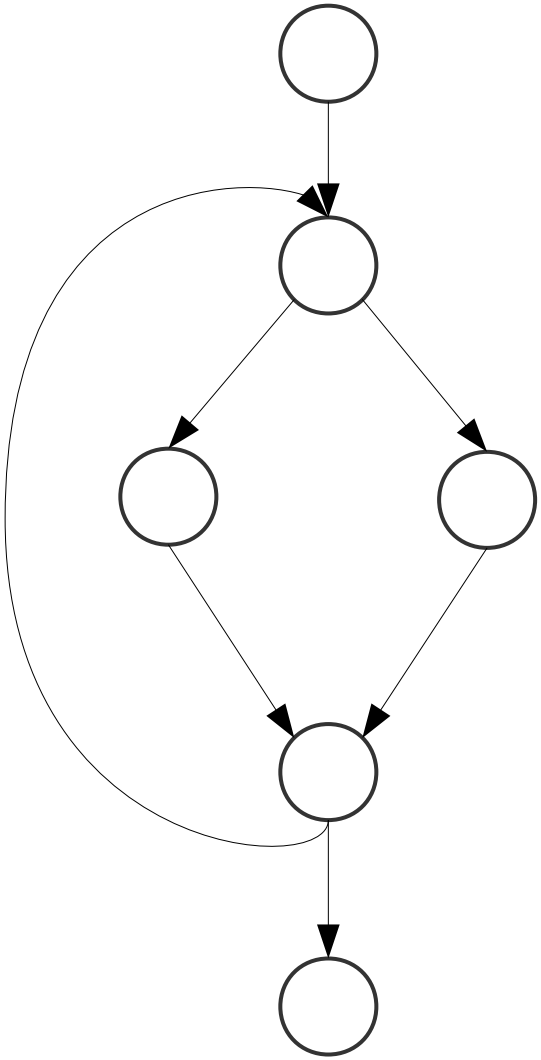
Borrow

Each Borrow expression will corresponding to each Loan

```
Loan L0 {
    point: P1,
    path:  x,
    kind:  shared
    region: '1 {
        P1 …
    }
}
```



The Data Flow of the Loan



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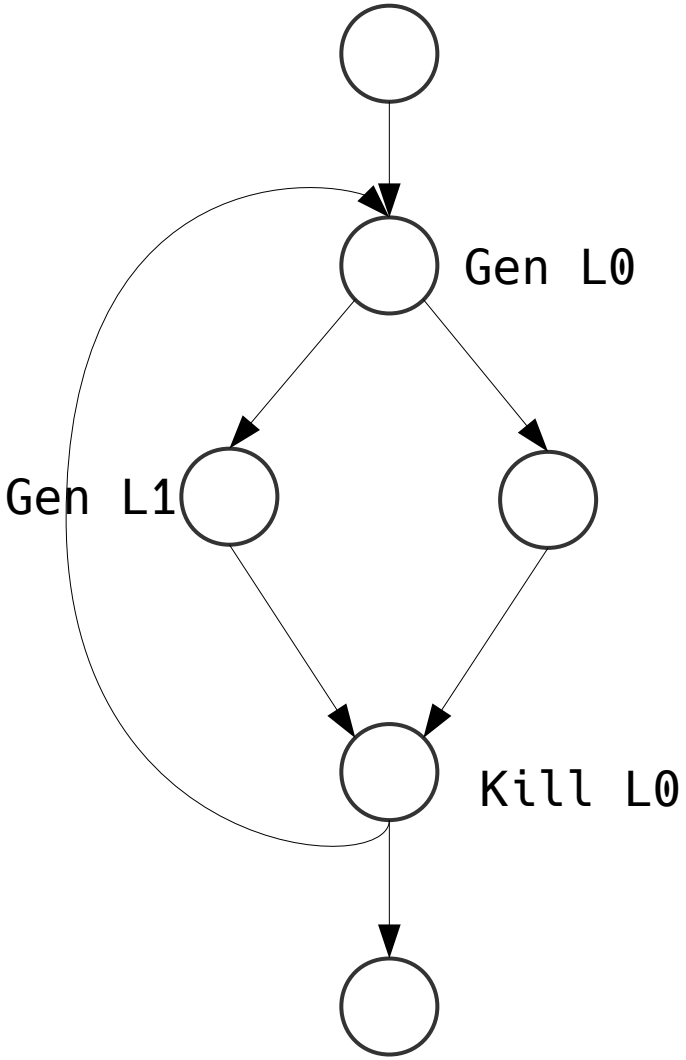

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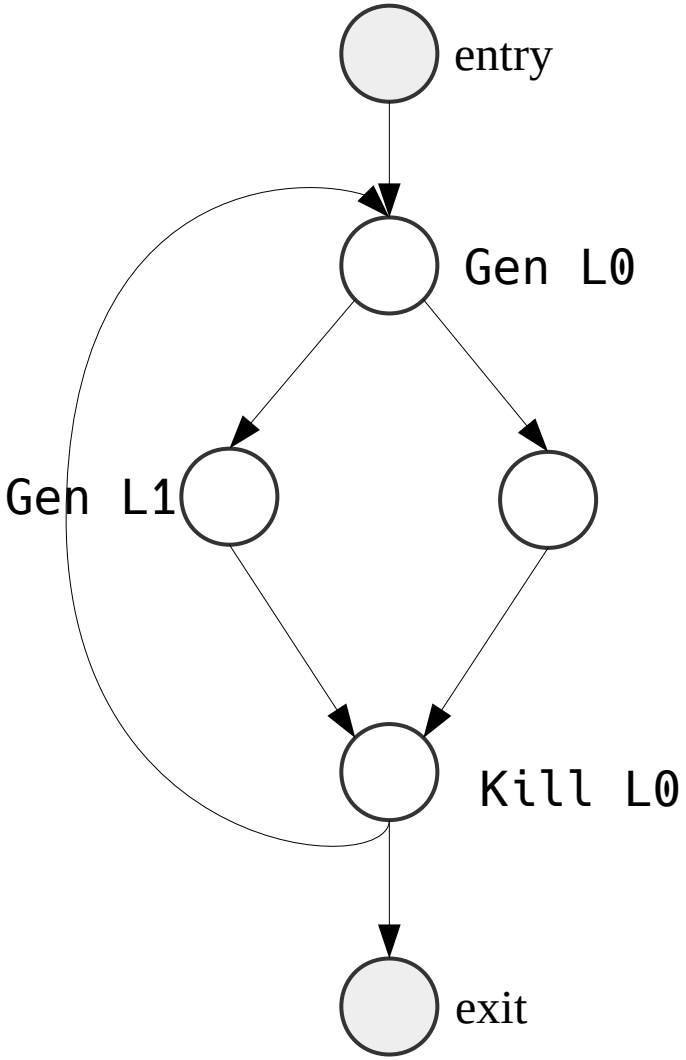

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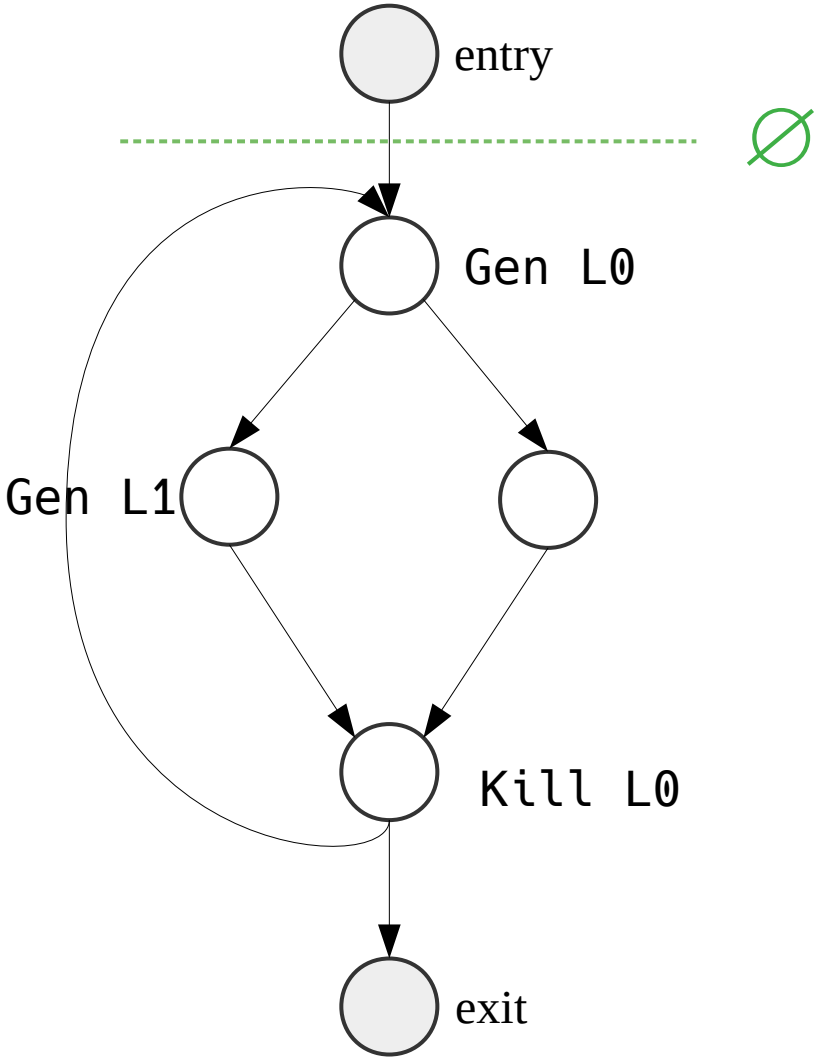

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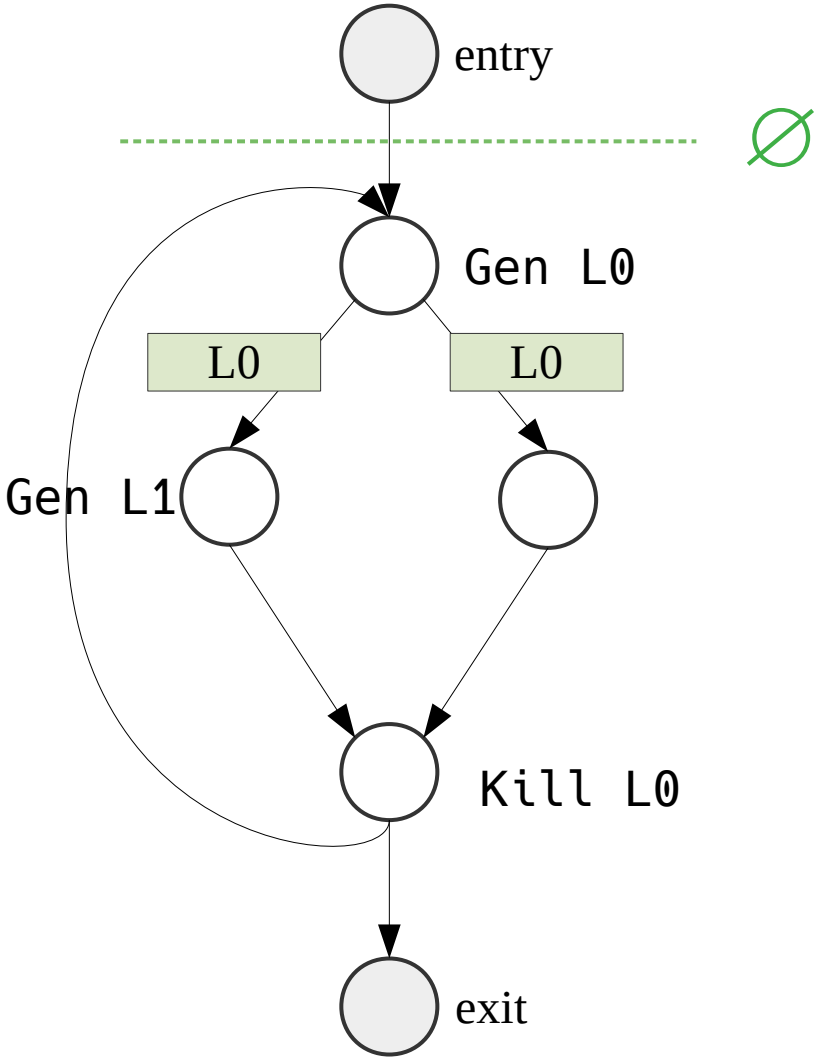

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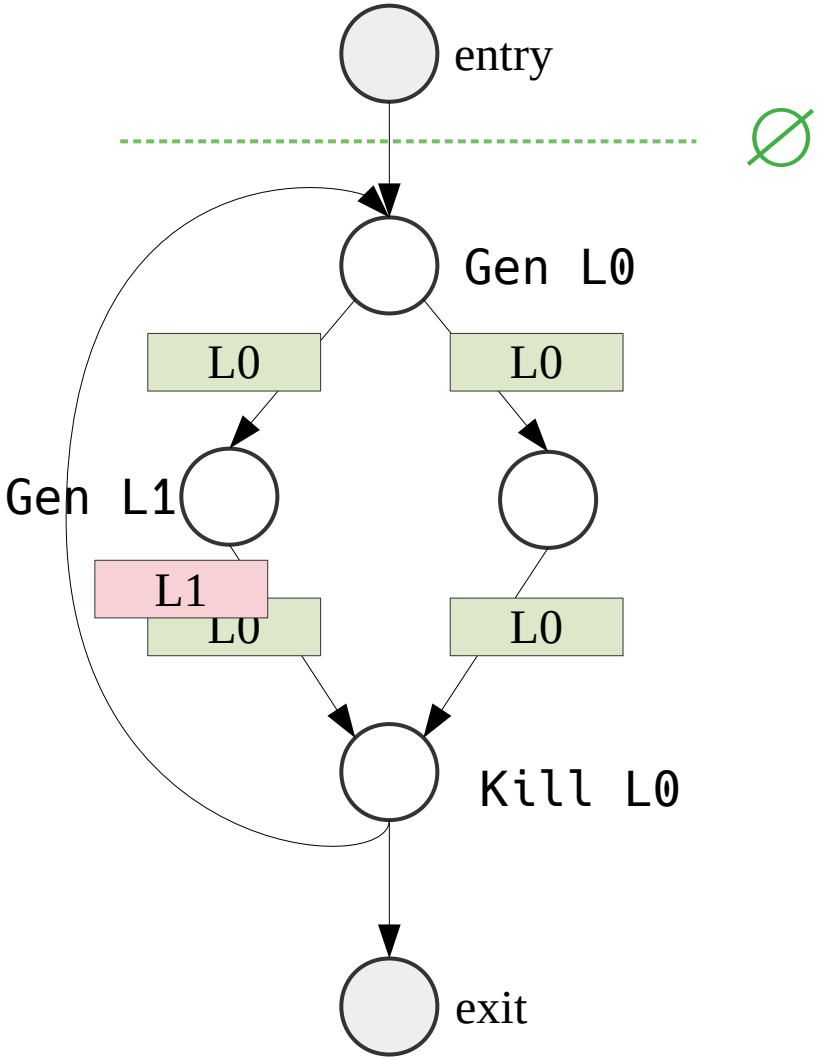

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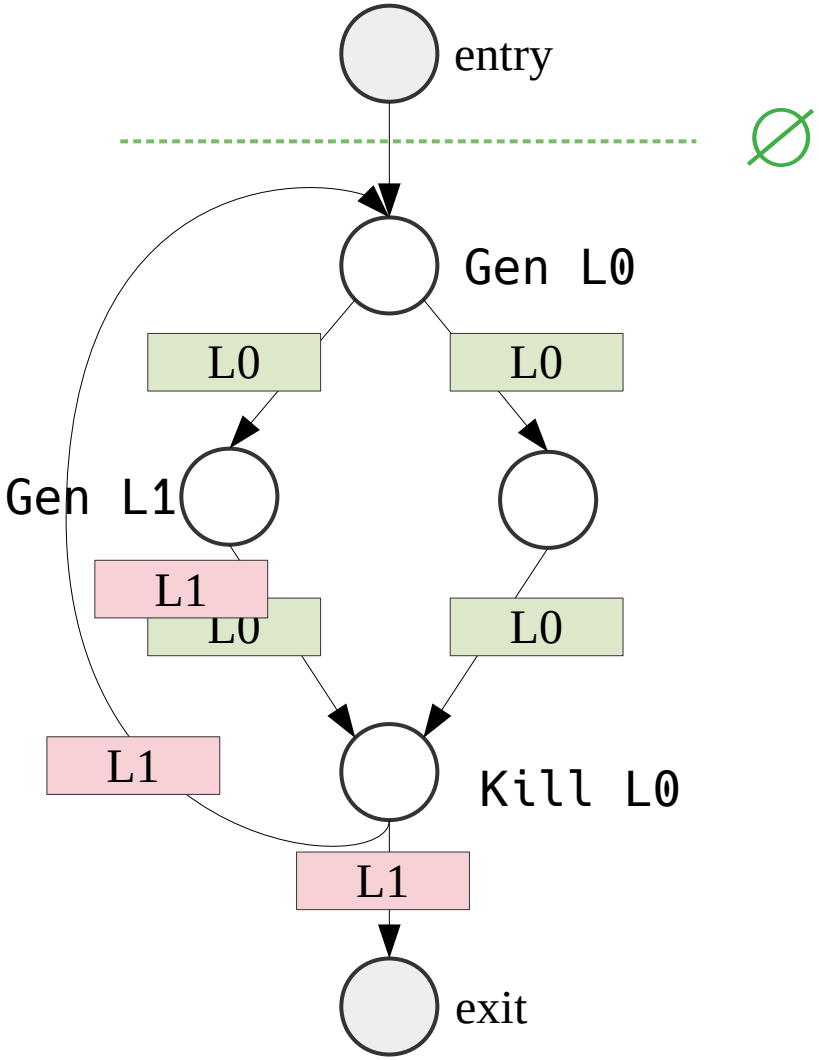

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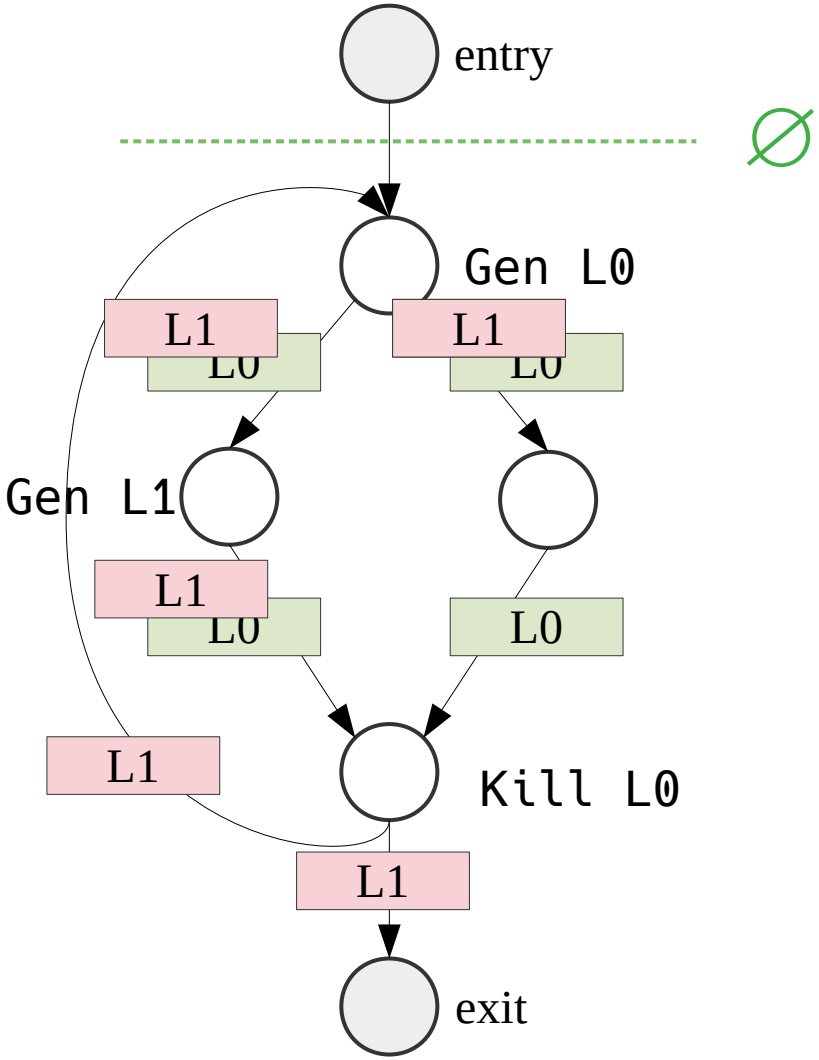

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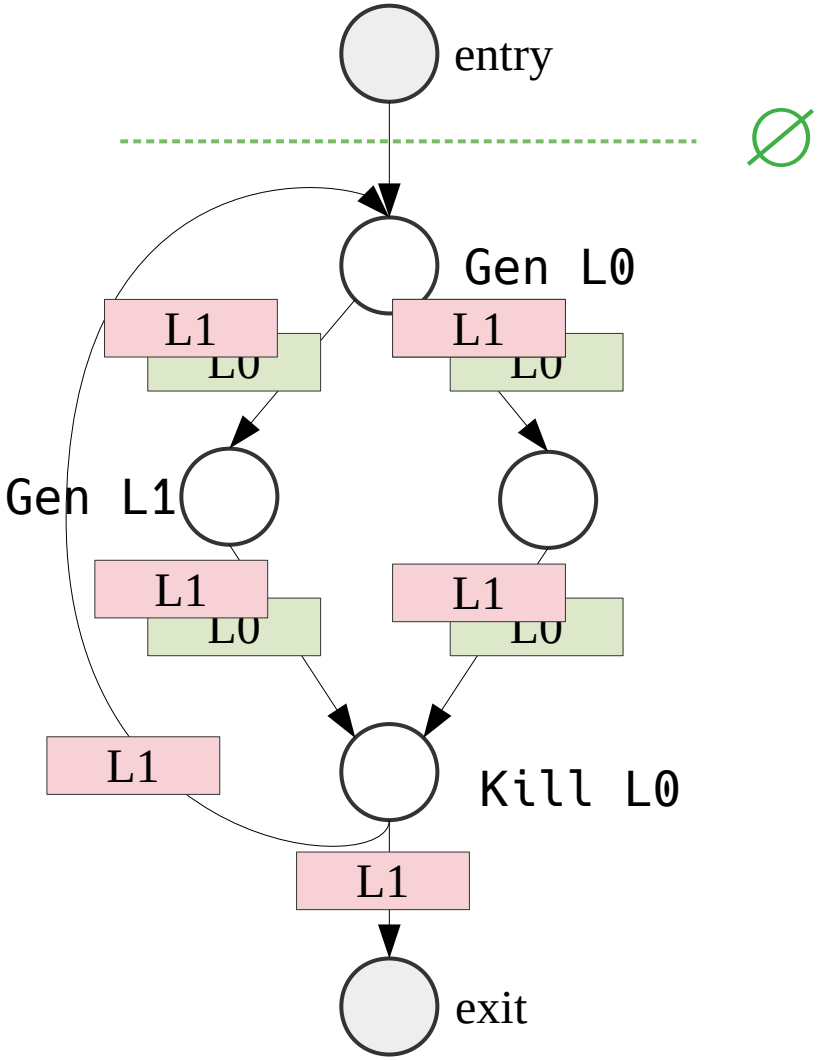
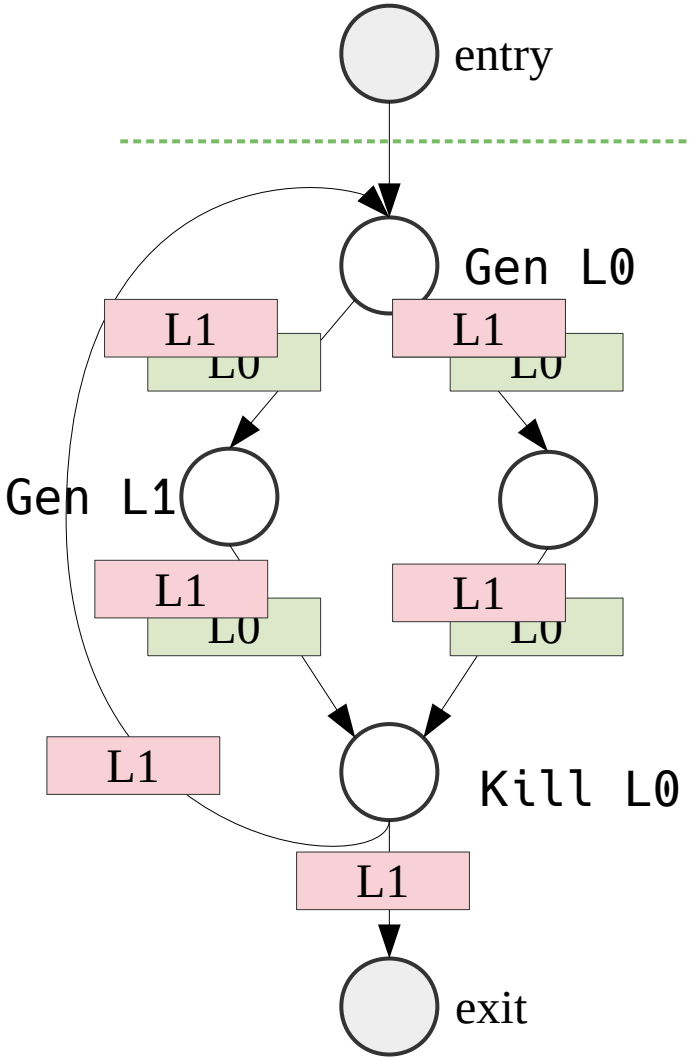


The Data Flow of the Loan

Key: which loan live at which points



When all the sets are stable, that's mean **the state is not changed anymore**, then the data flow computation is complete.

When to Gen, Kill

Gen Loan :

If it’s a borrow expression, then gen a Loan

Kill Loan :

1) $\texttt{LV = Loan}_i\texttt{ . path}$
2) $\texttt{point} \notin \texttt{Loan}_i\texttt{ . region}$

Example

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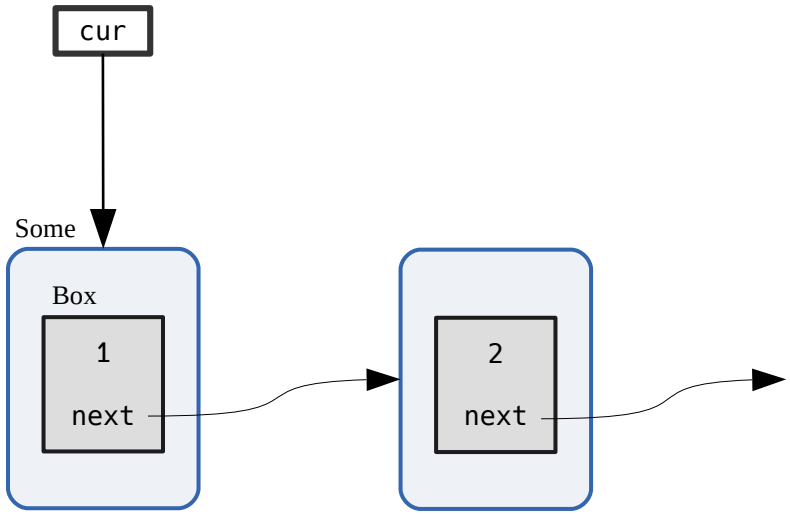

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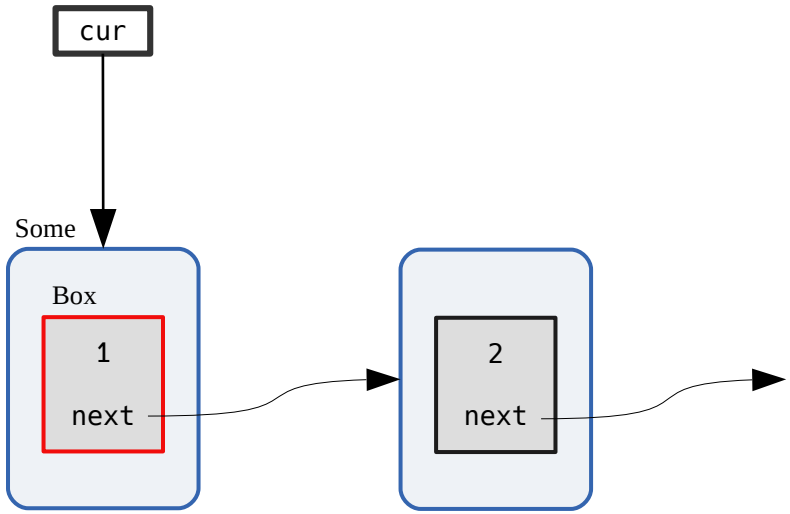

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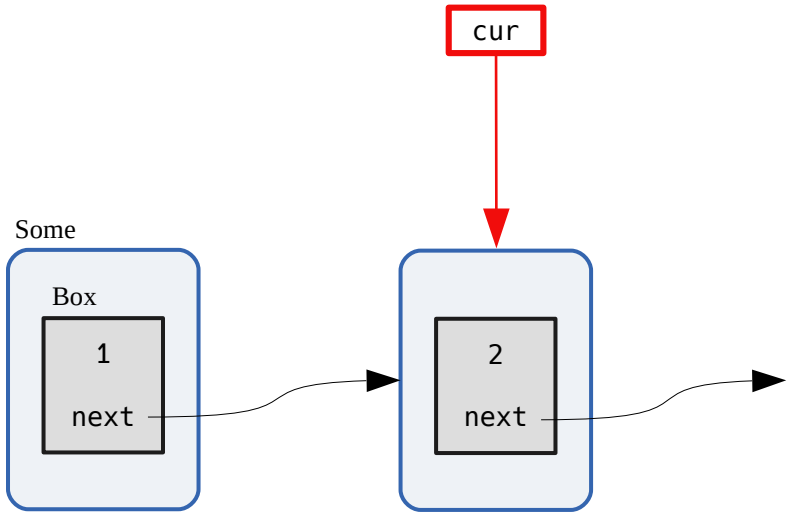

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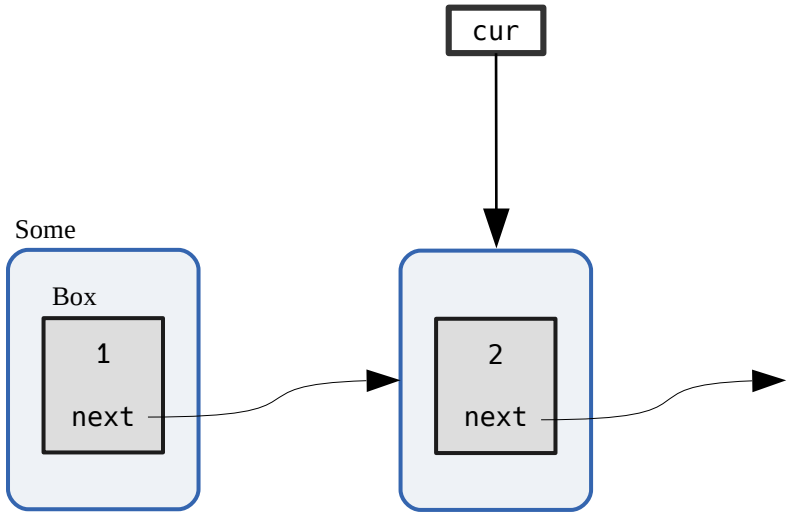

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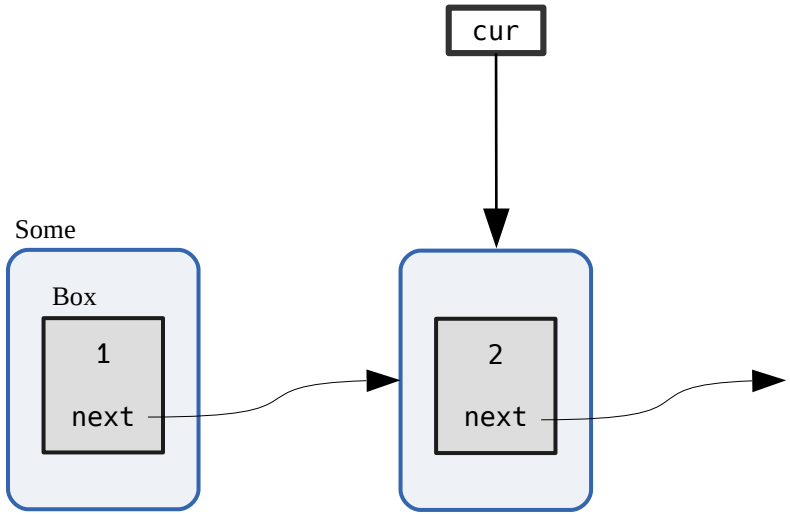
L2



Example

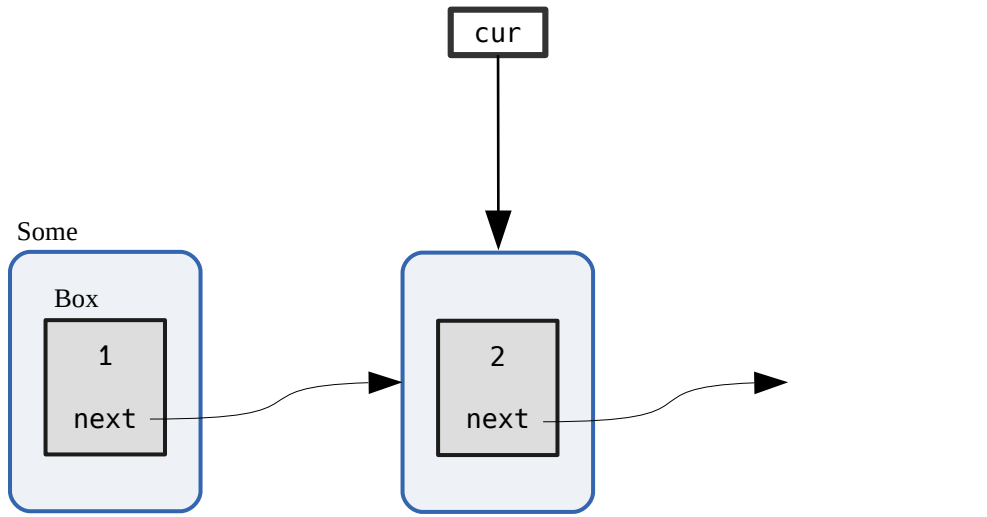
```
fn do_something(mut head: Option<Box<ListNode>>)
{
    let mut cur = &mut head;

    if let Some(nodeBox) = cur.as_mut() {

        cur = &mut nodeBox.next;

        println!("{:?}", nodeBox);
    }

}
```



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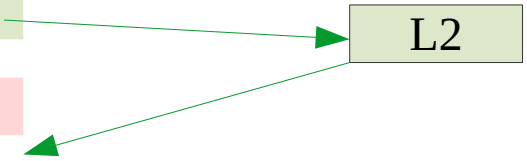

Why `**L2'** live at this point ?

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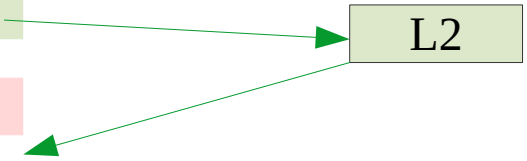

Why `**L2'** live at this point ?

1. no assignment to { nodeBox, nodeBox.next }
2. `**cur'** will be used later

參考題目

Leetcode : remove linked list elements

Datafrog

The tool used in Rust’s new borrow checker called Polonius

Idea

- 每次都往前推論一步，直到每個節點都達到穩態即推論完畢

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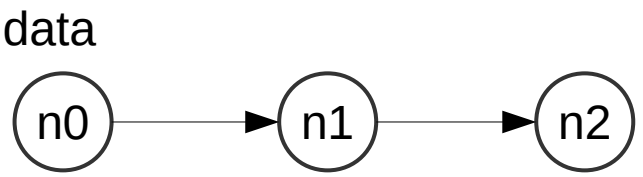

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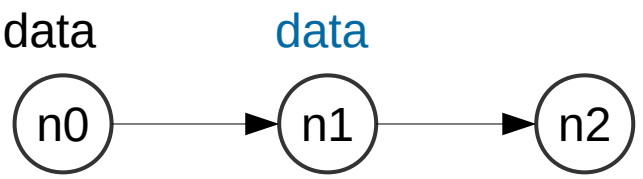

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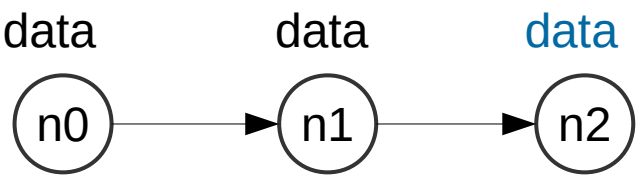
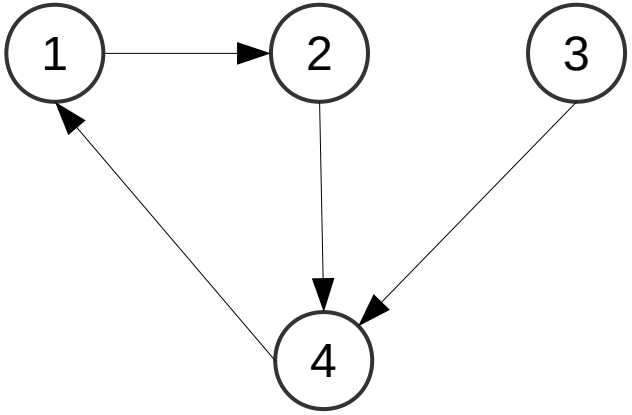


Example . Transitive Closure



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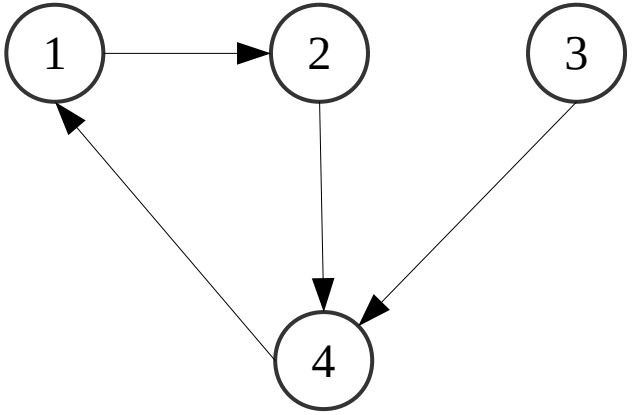
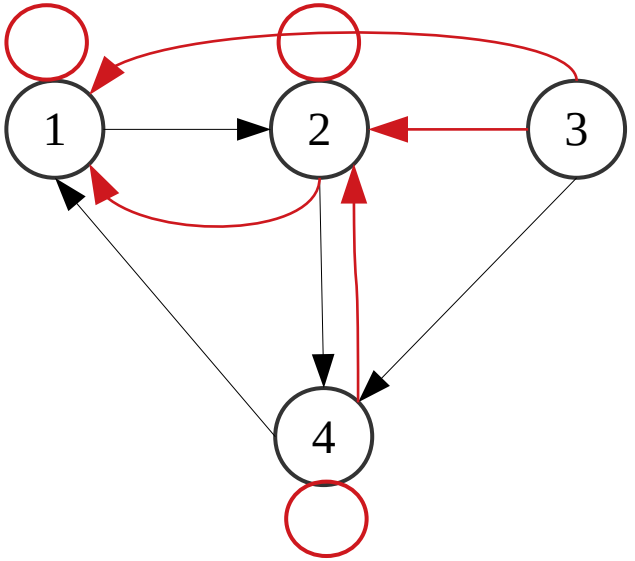


$$\frac{e(a,b)\quad e(b,c)}{e(a,c)}$$



Implementation – Initial

```
// create a iteration context
let mut iteration = Iteration::new();

// create some variables for later use
let v_edges  = iteration.variable::<(u32, u32)>("edges");
let v_redges = iteration.variable::<(u32, u32)>("reverse edges");

// load the initial variables
v_edges.insert(edges.into());

// start iteration
while iteartion.changed() {

    ...


}


let result = v_edges.complete();
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Writing Rules here

Implementation – Writing Rules

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while iteration.changed() {
    // reverse edges for mapping
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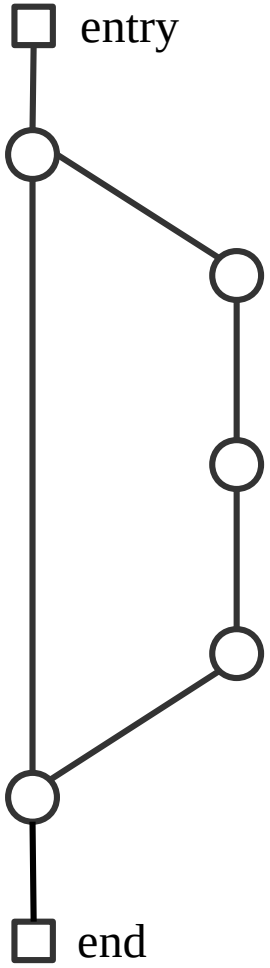
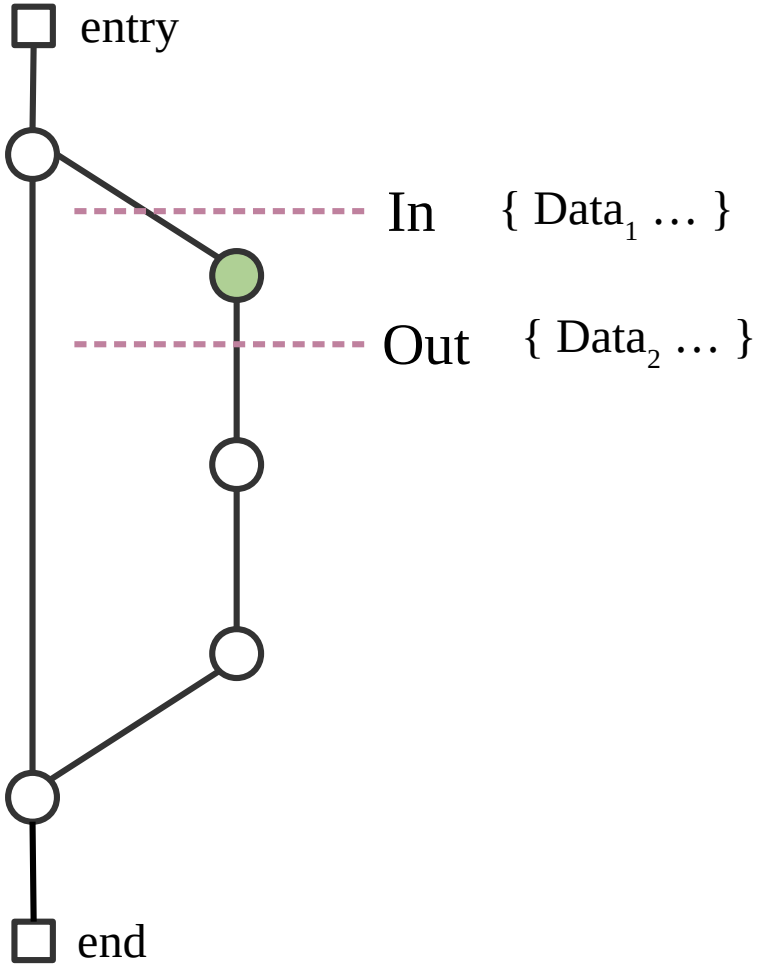
QA

Data Flow Concepts <D, V, ∧, F>



Data Flow Concepts <D, V, ∧, F>



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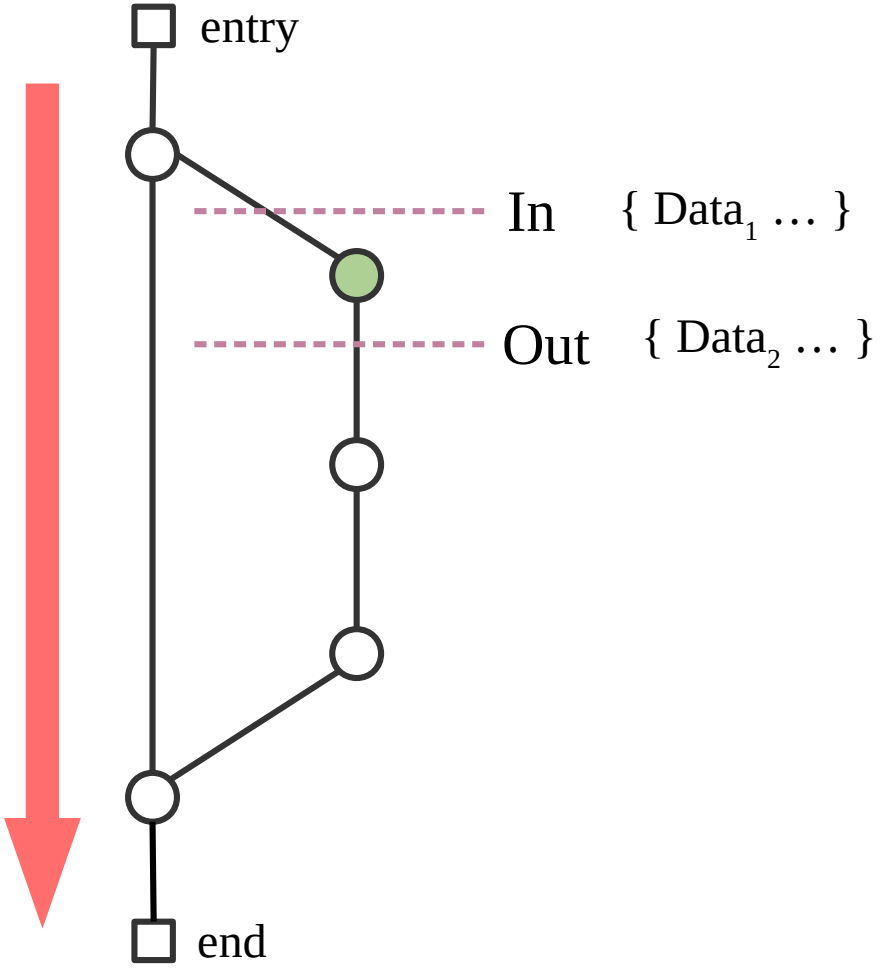

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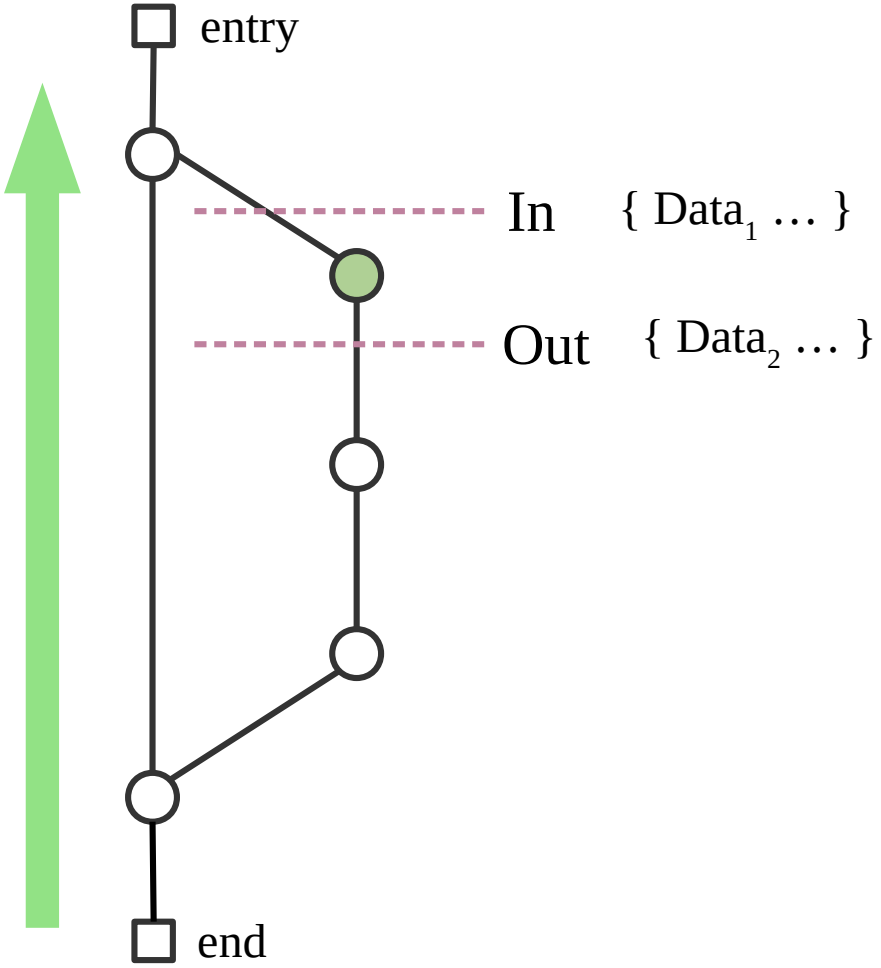

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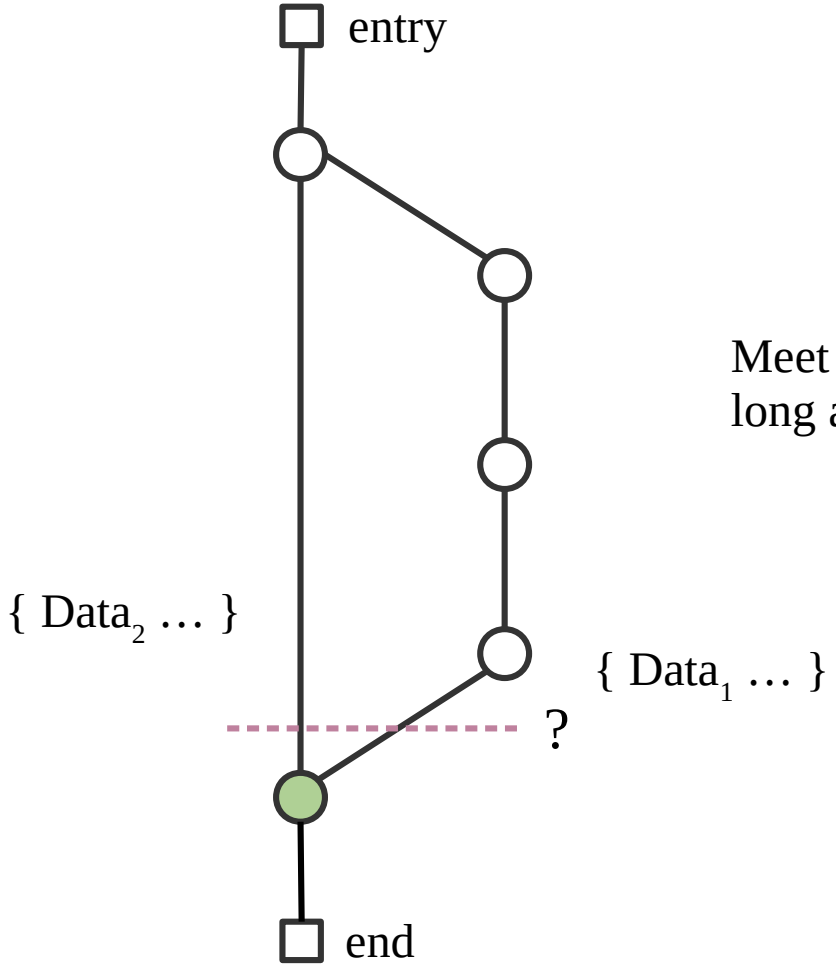
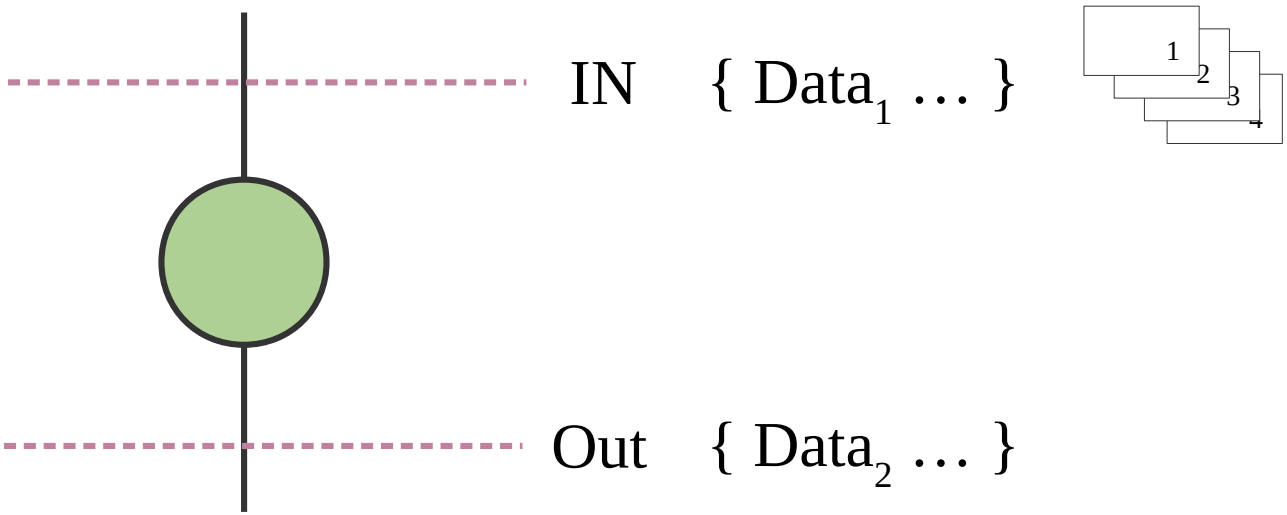


Meet operator can be union, intersenction, as long as it can make (V, ∧) semilattice.

Data Flow Concepts <D, V, ∧, F>



Data Flow Concepts <D, V, ∧, **F**>