VisualAI:
A Framework for Interactive Abstract Interpretation

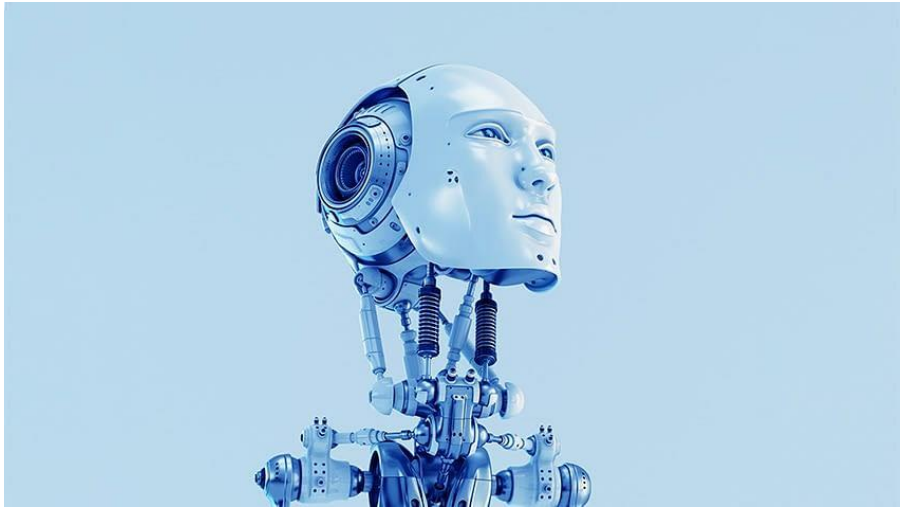
Jung Hyun Kim

SoftSec Lab., KAIST

IS661 Spring, 2024

AI?

AI?



Artificial Intelligence
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AI is important in program analysis.

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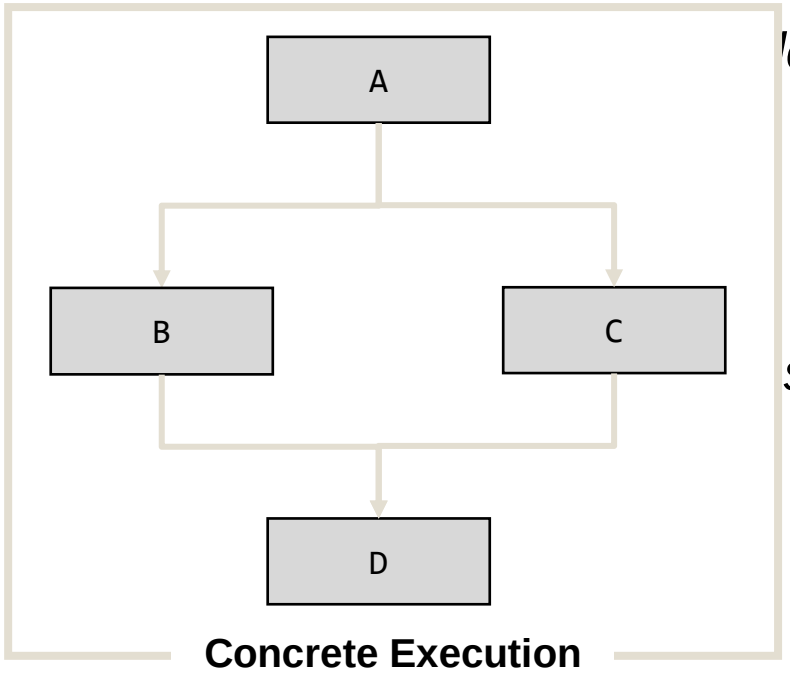
Difficulties In Visualizing AI



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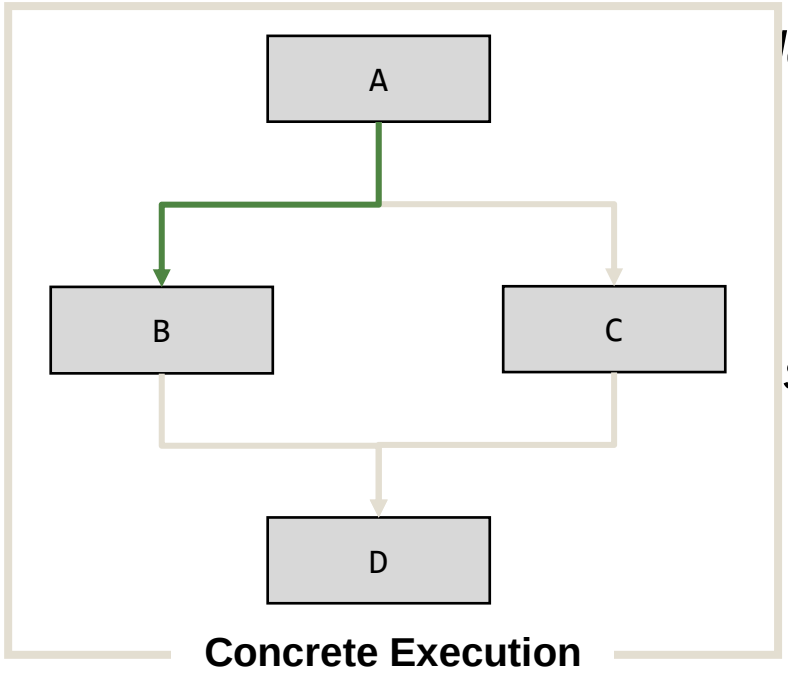

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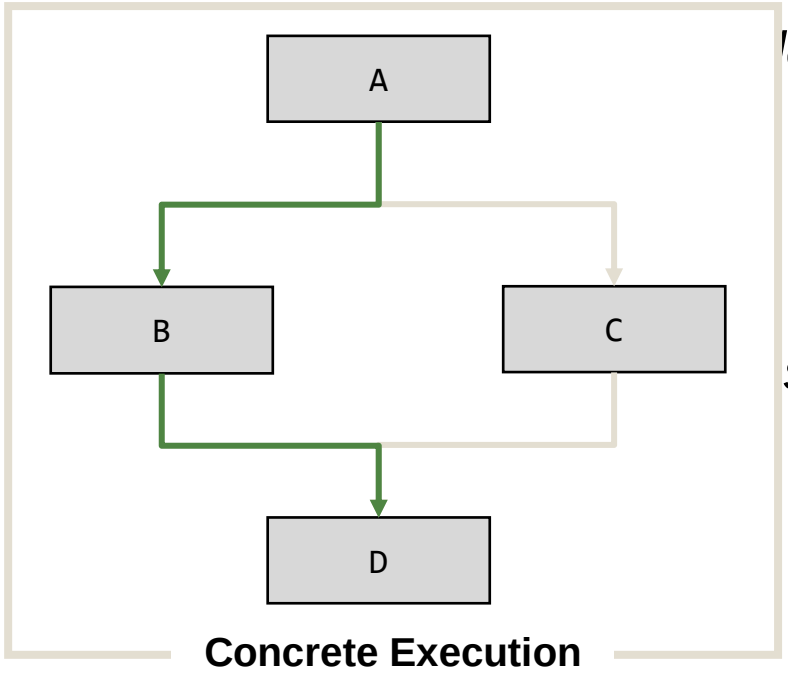

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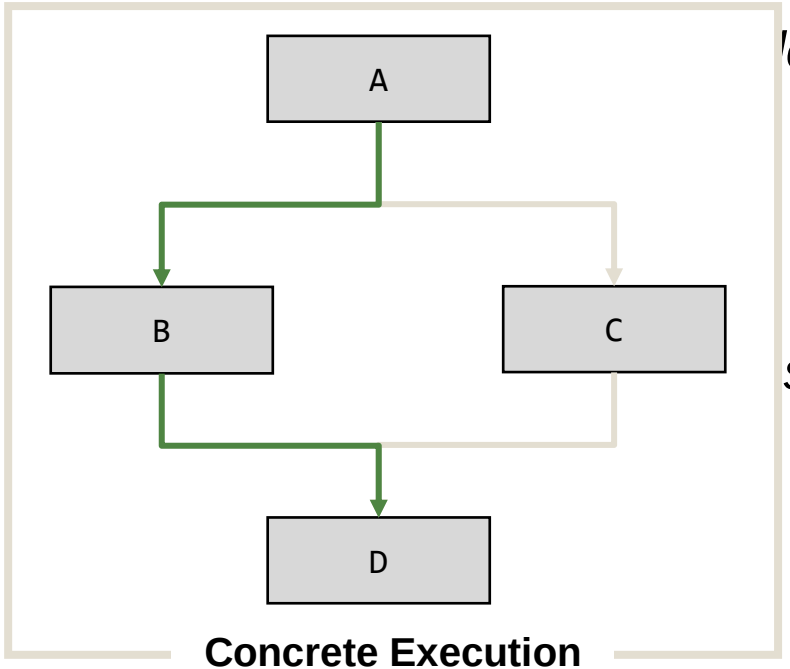

Concrete Execution

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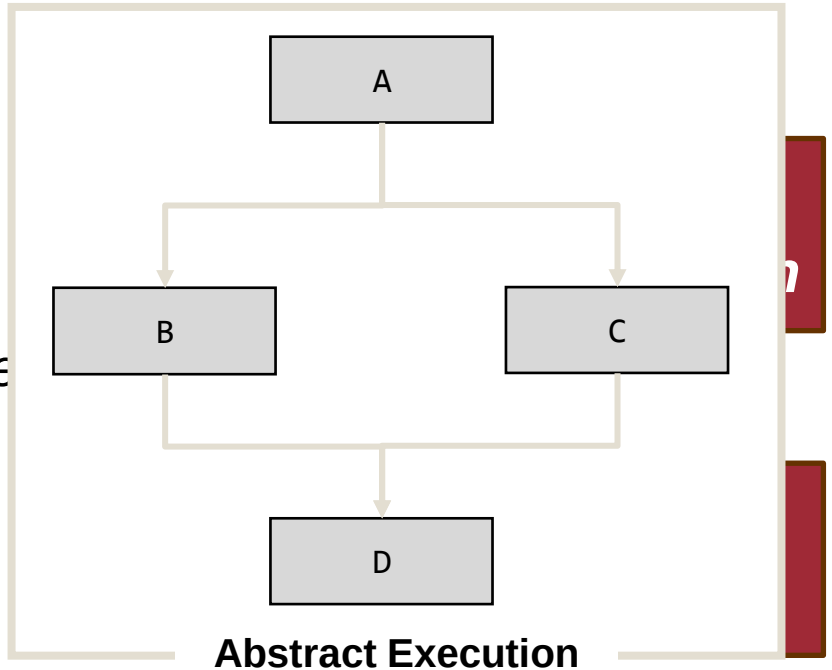

Abstract Execution

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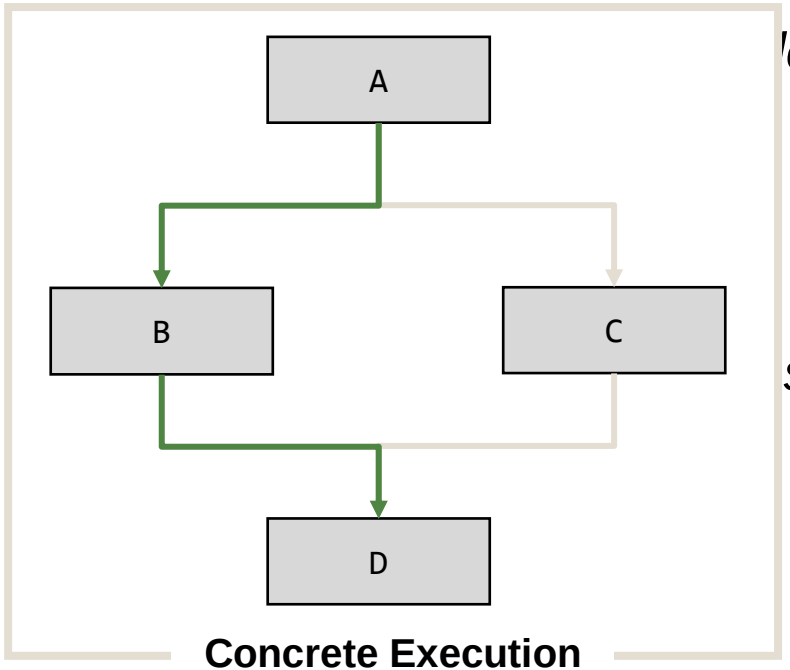

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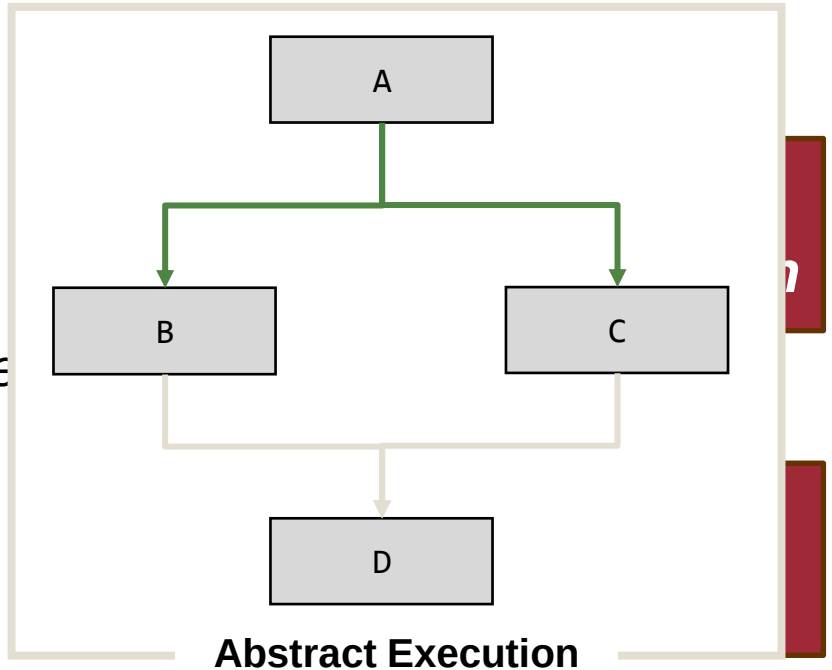

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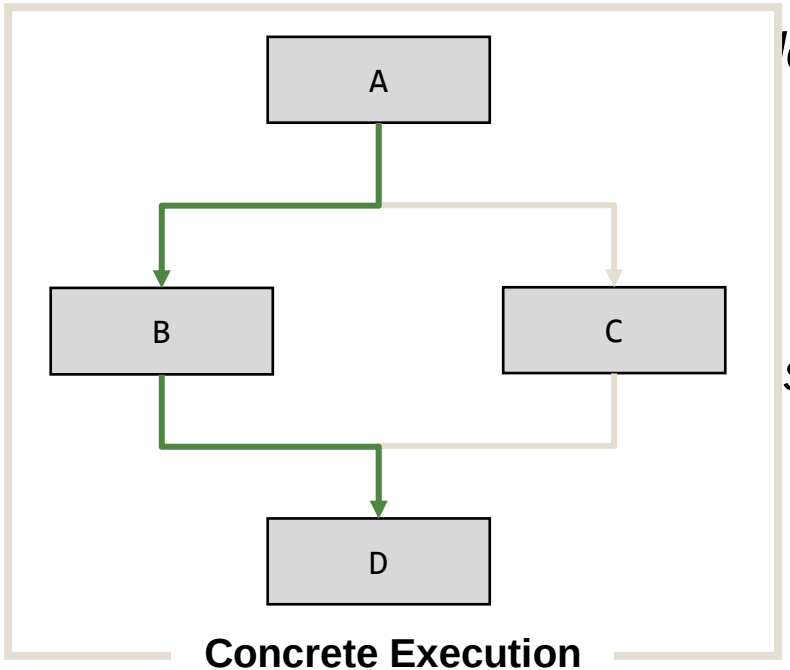

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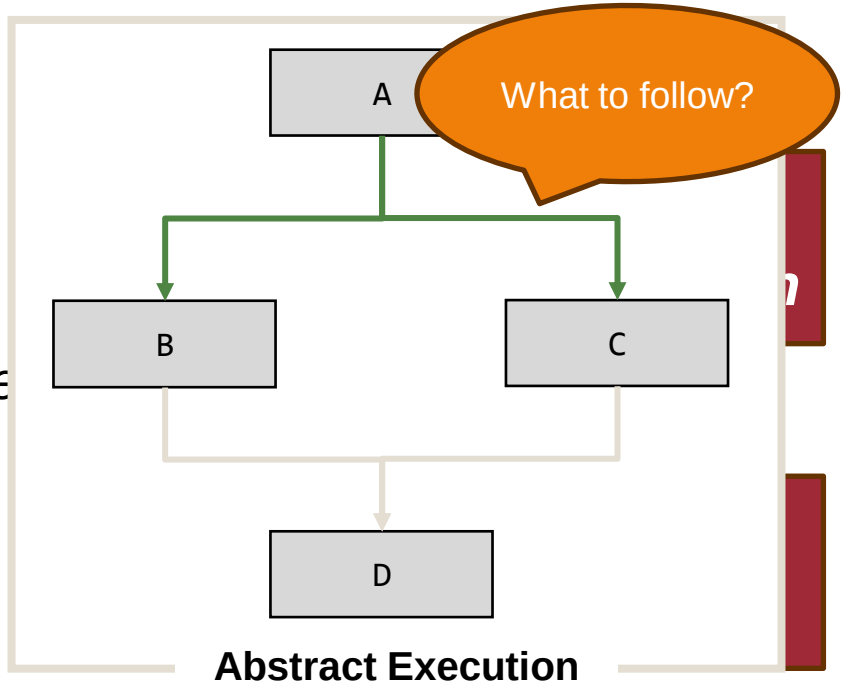

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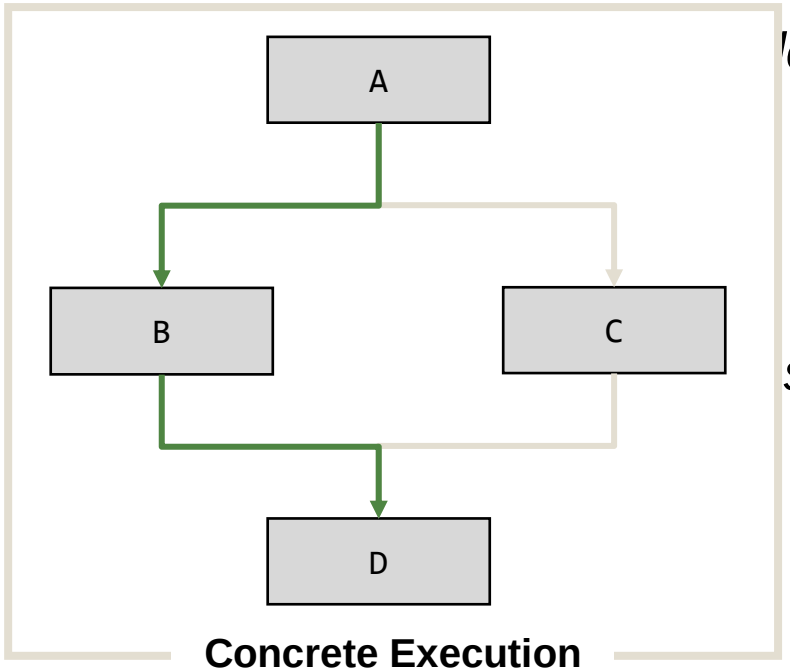

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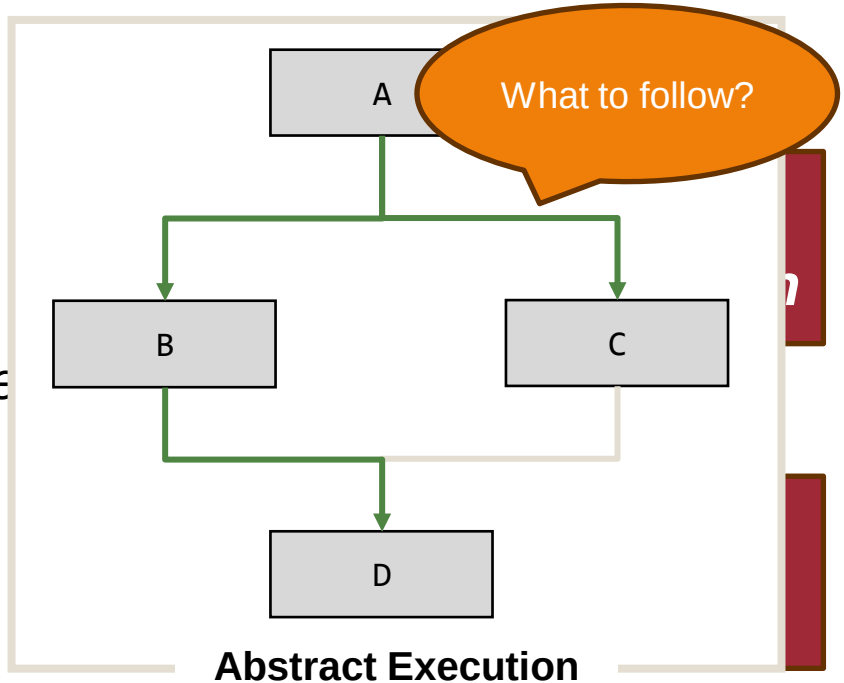

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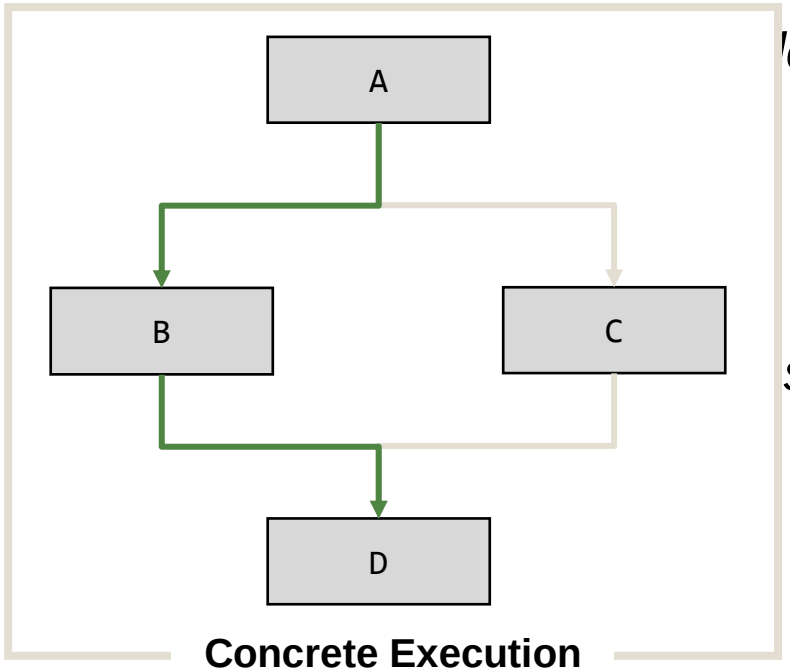

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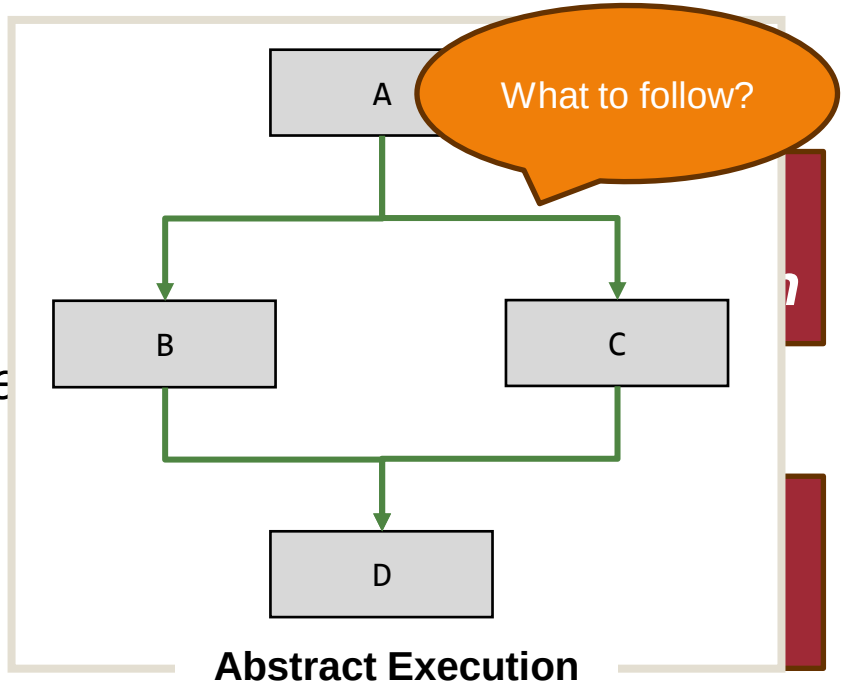

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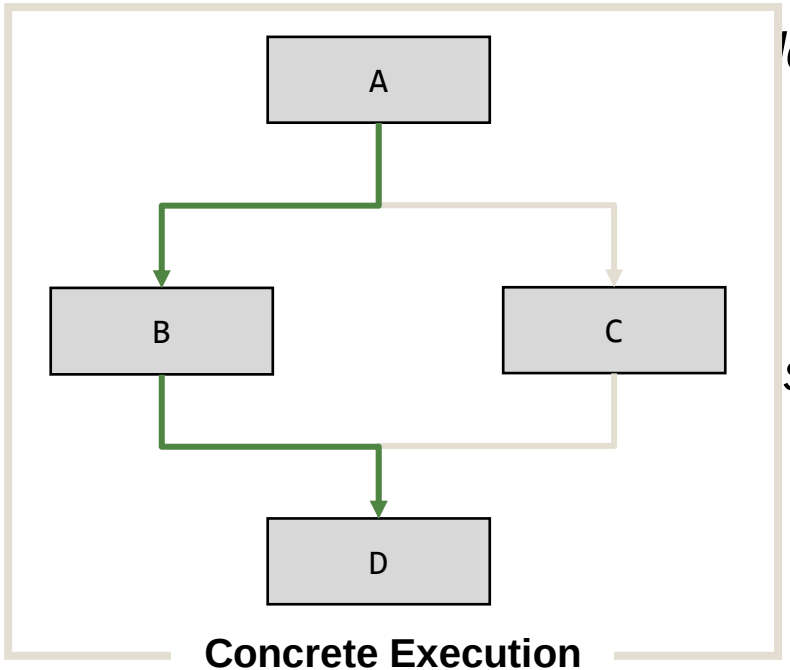

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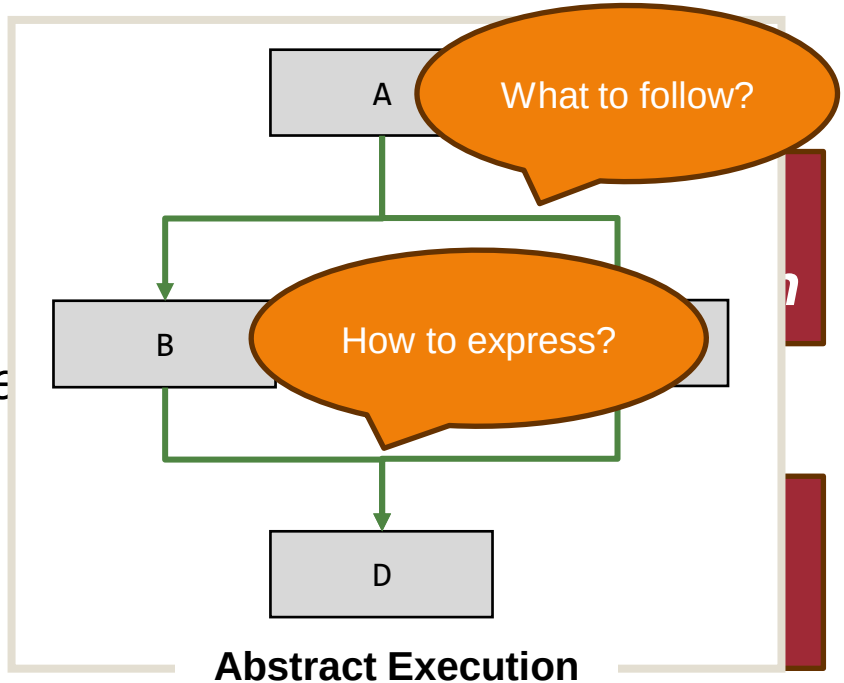

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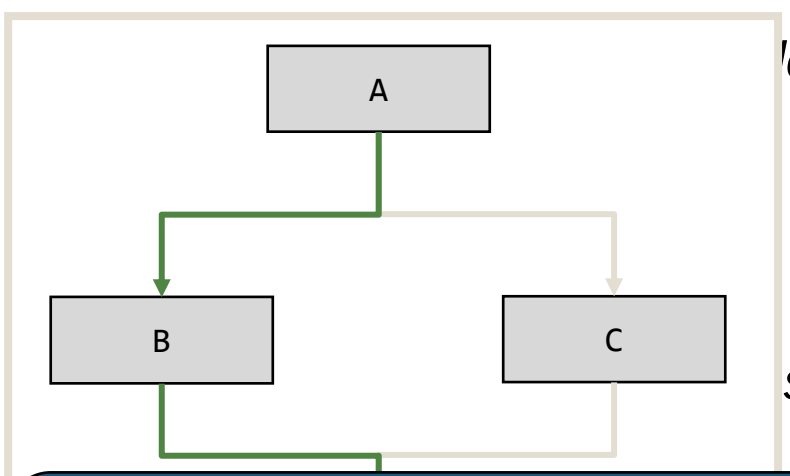

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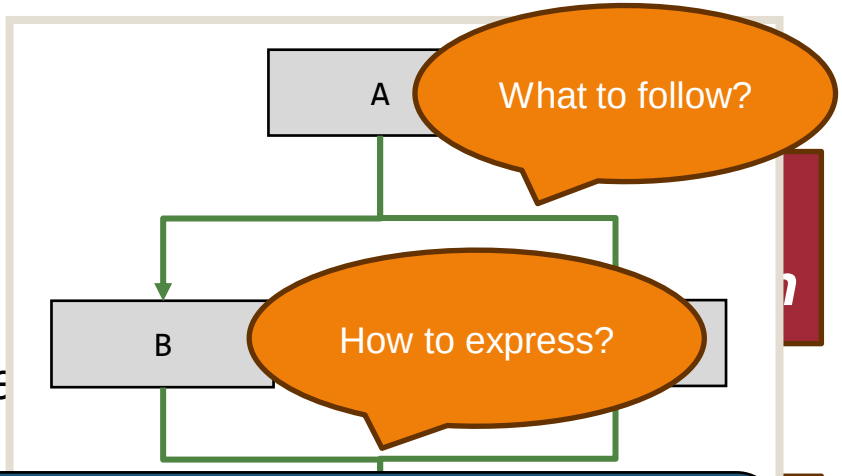

How could we *visualize* AI in an *interactive* manner?

VisualAI: An Interactive Visualizer for AI

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- Provides a *visualization* of an AI process.

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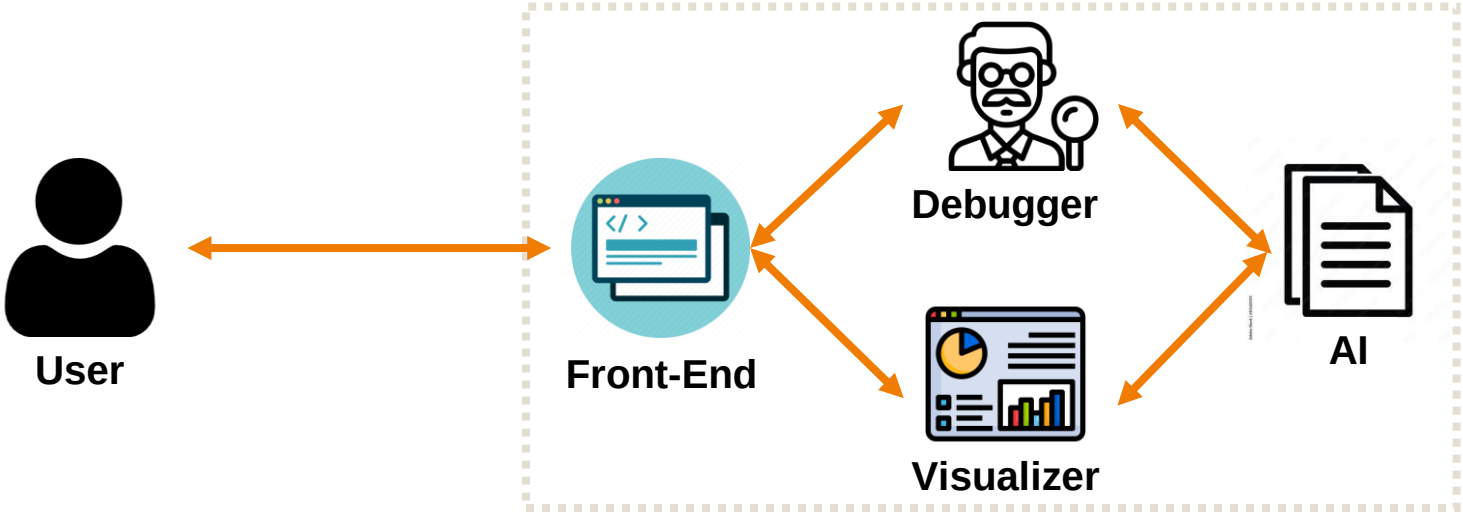

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Aims helping both students and researchers to understand AI better.

Expected Impact

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- Not only for research but also for study could it be useful.

Visualizer

Visualizer

- Visualize each state that an AI process can have by using SSA Graph and State Dependence Graph (SDG).

Visualizer

```
void main() {
  for(int i = 0; i < 10; i++);
}
```

Source code

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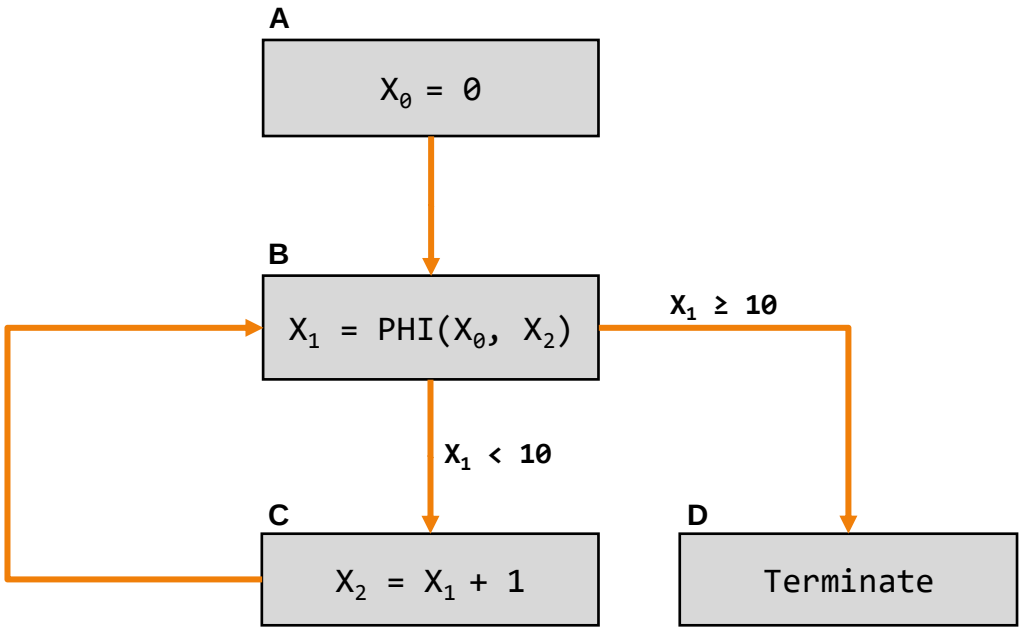

SSA Graph

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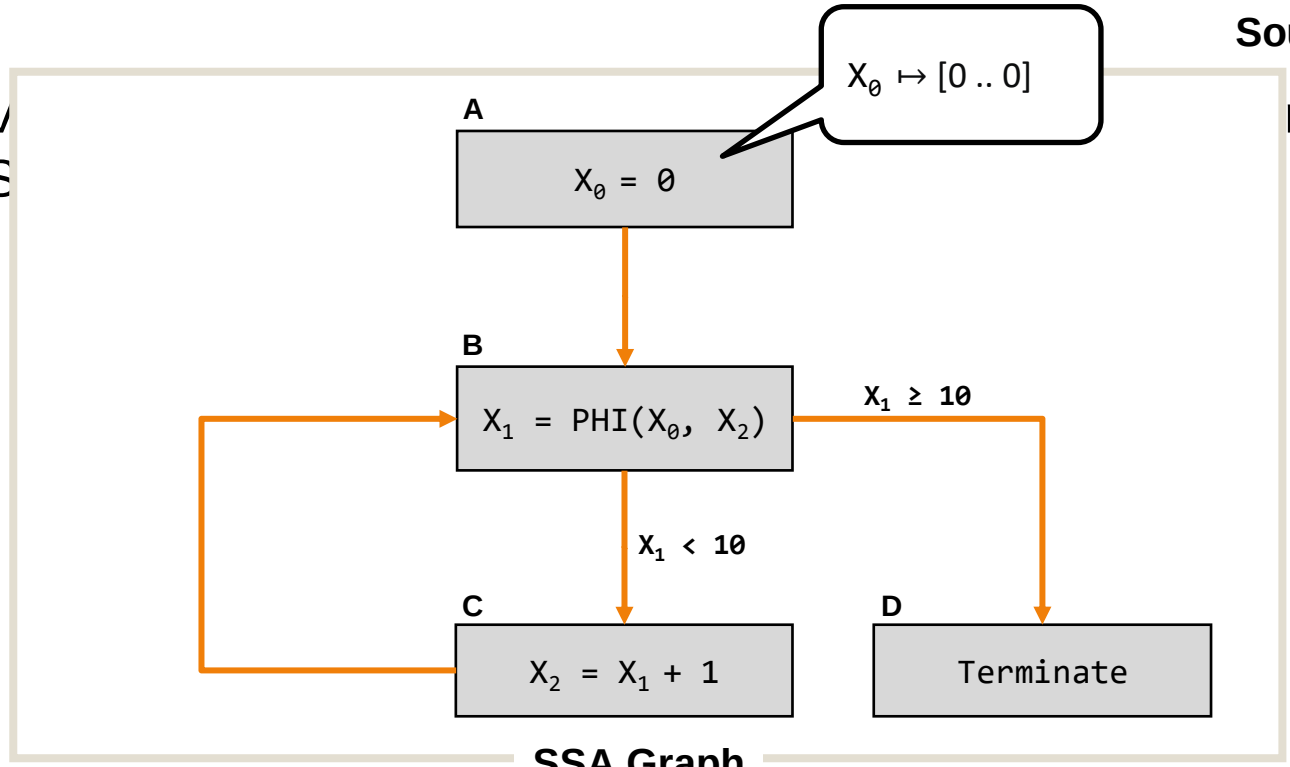

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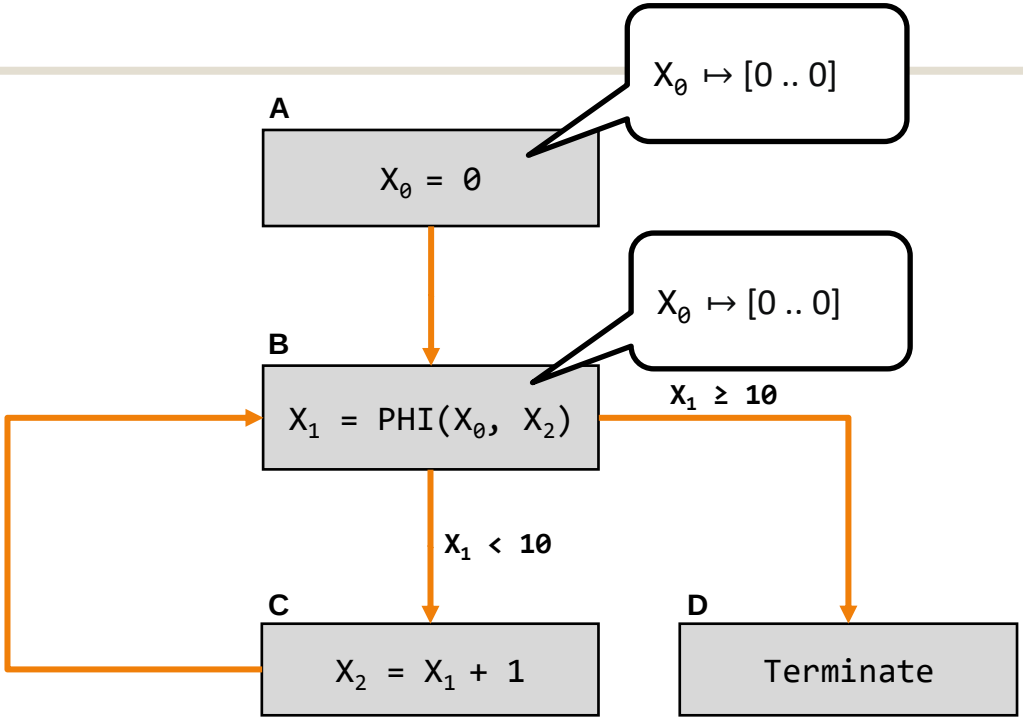

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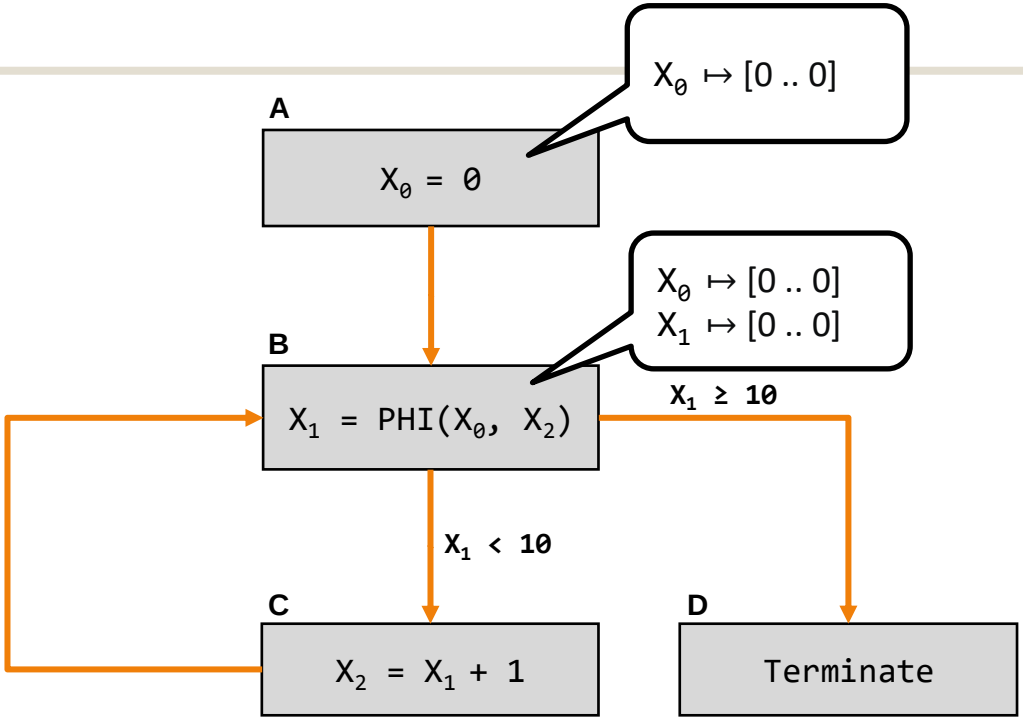

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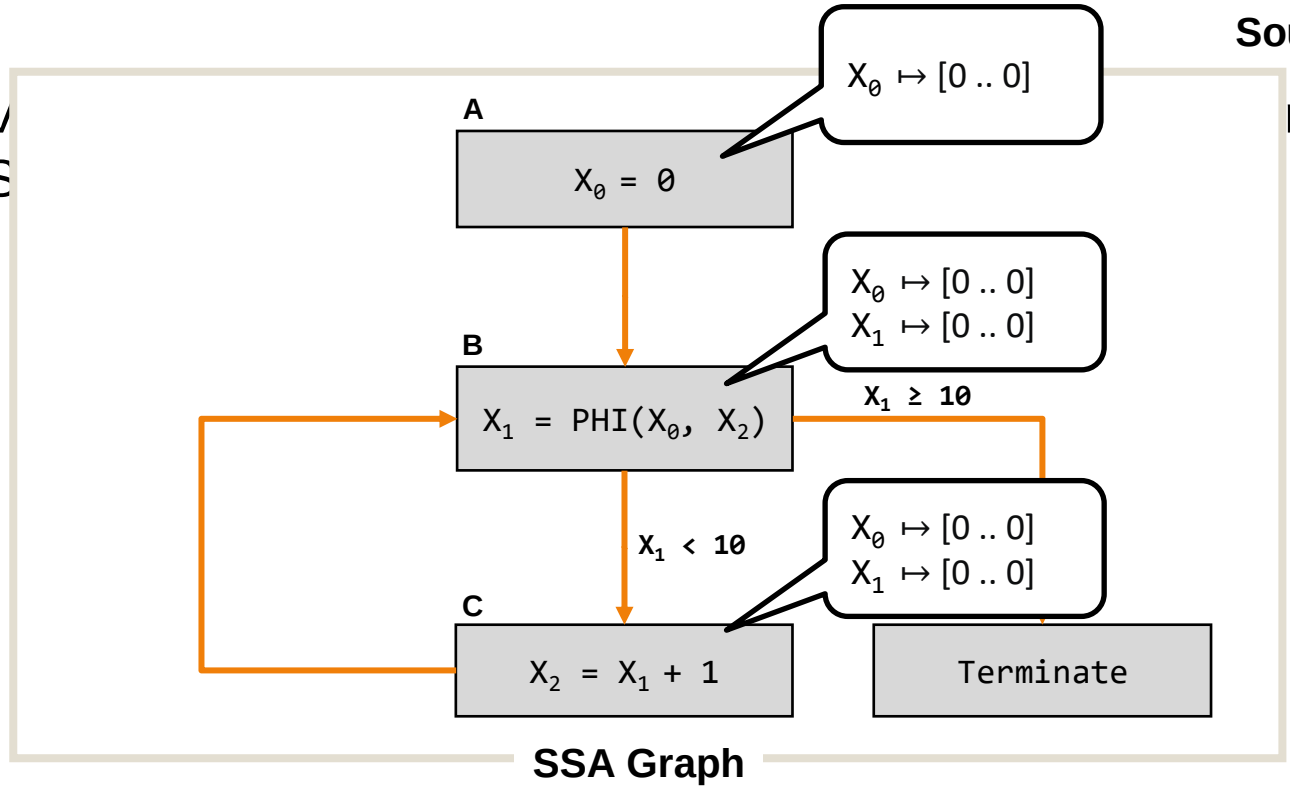

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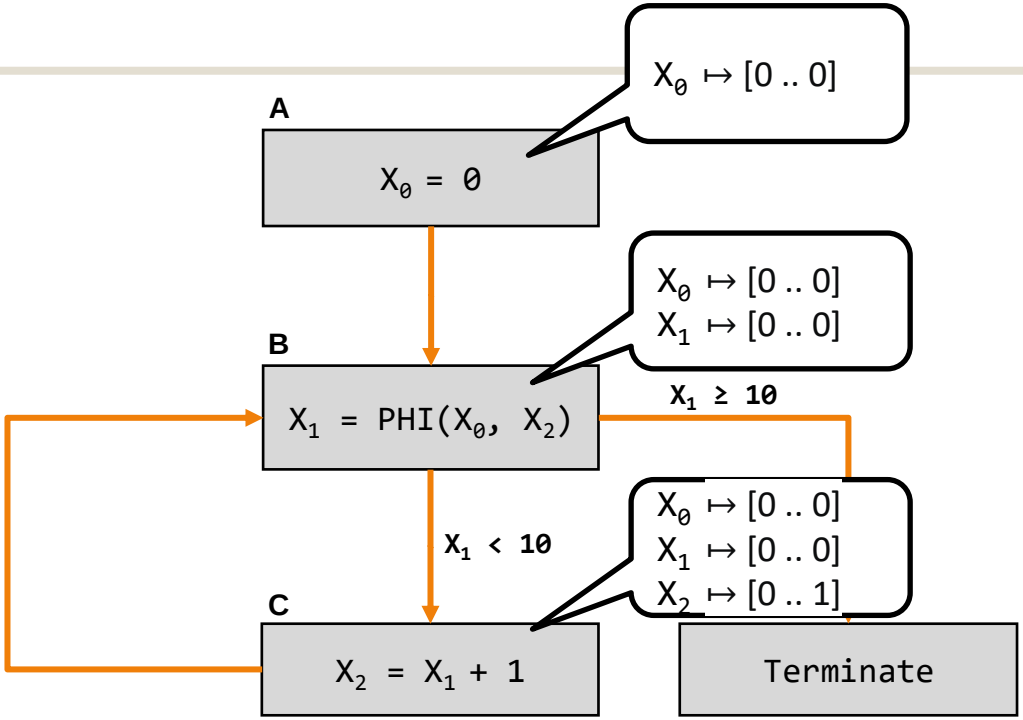

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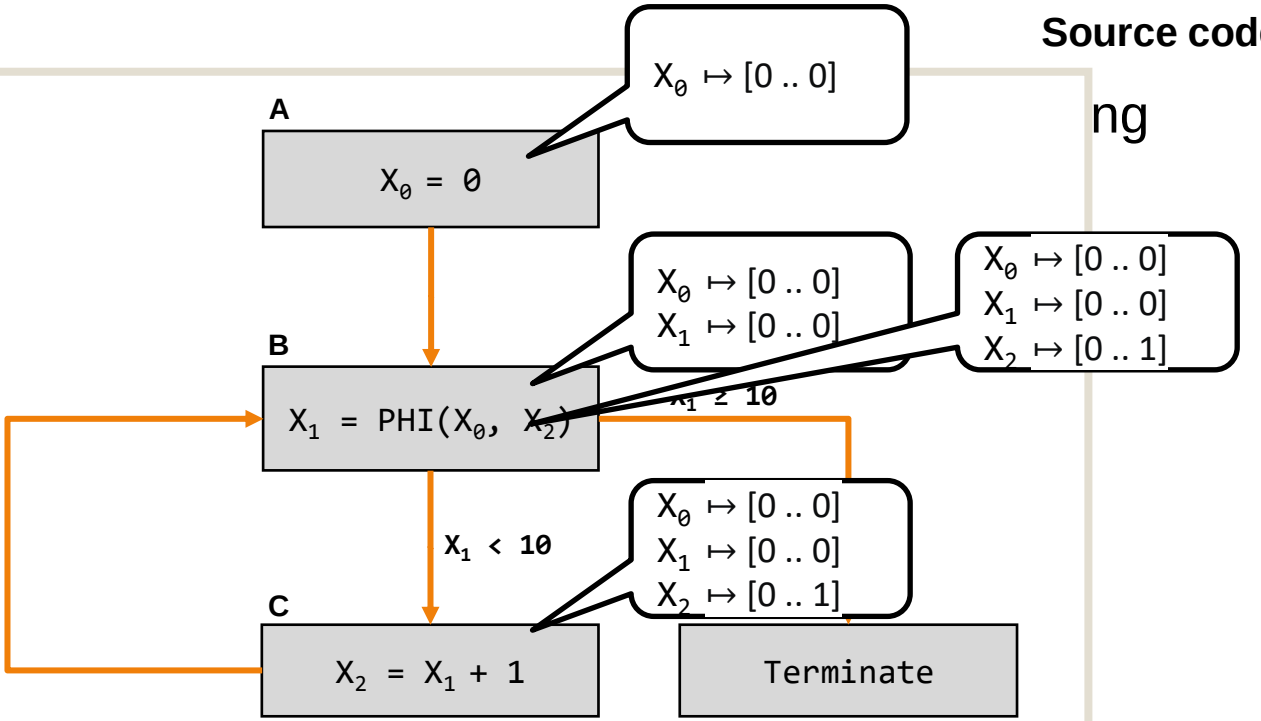

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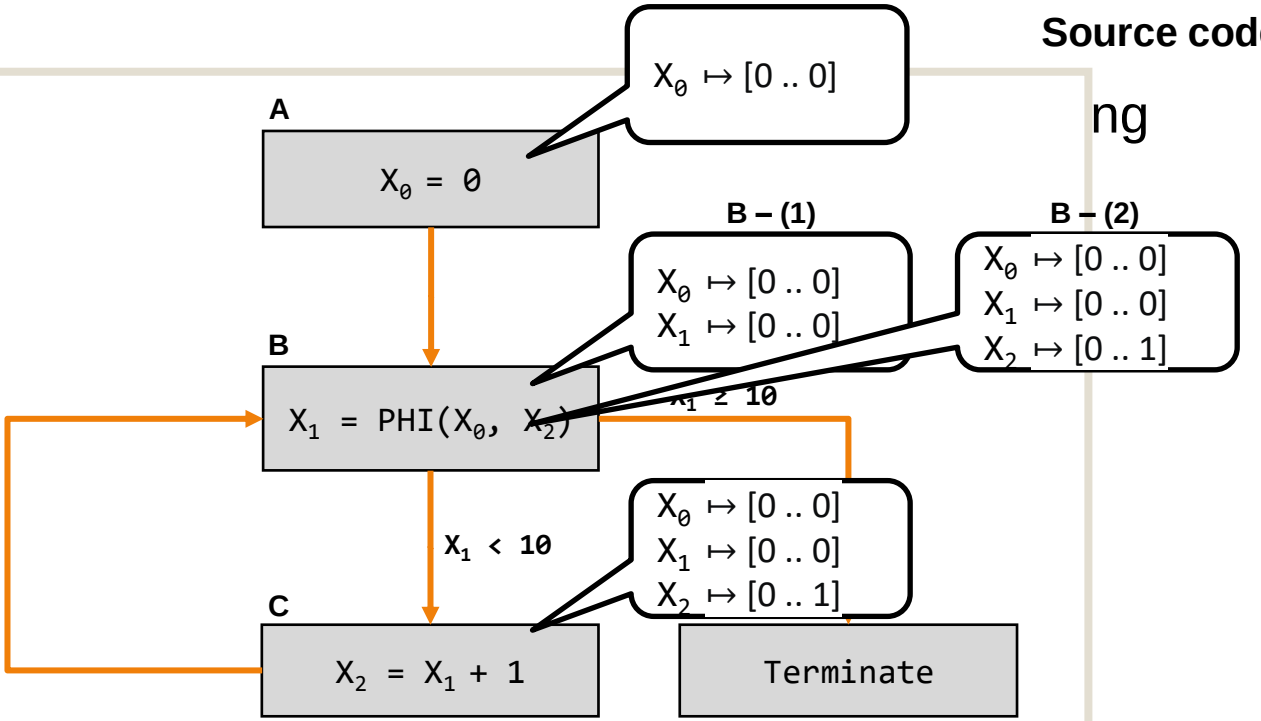

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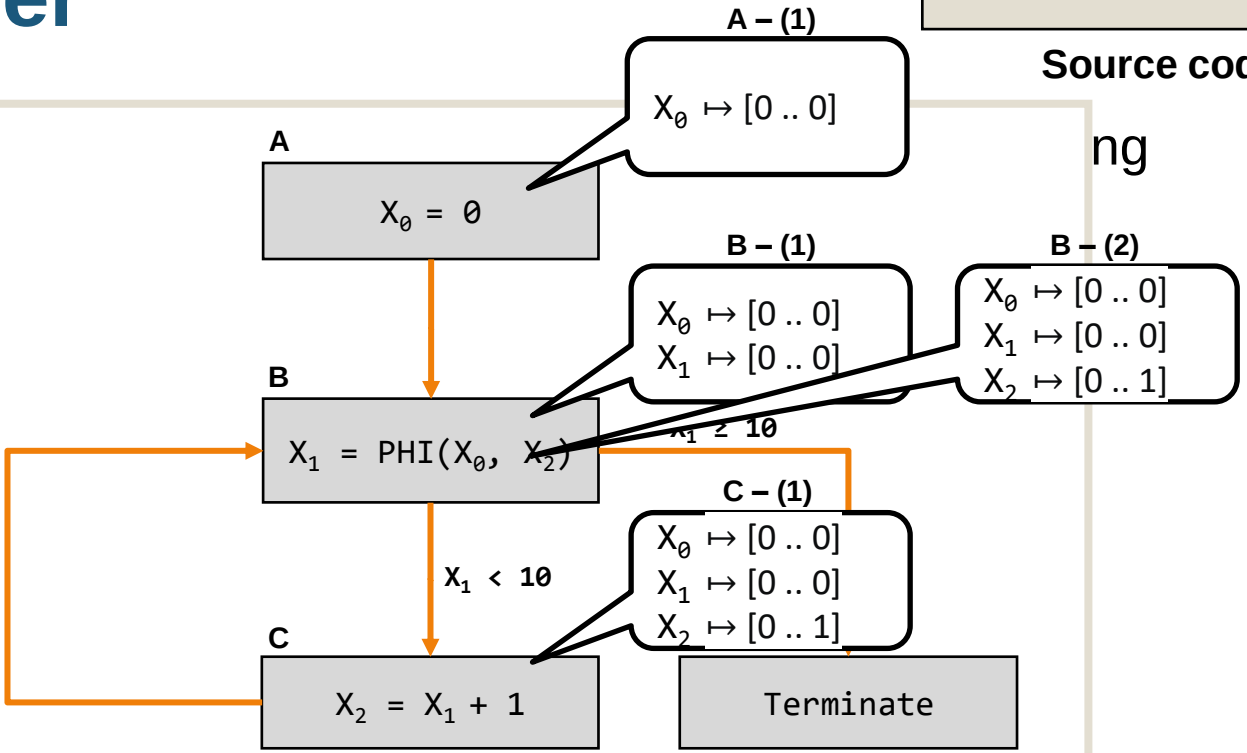

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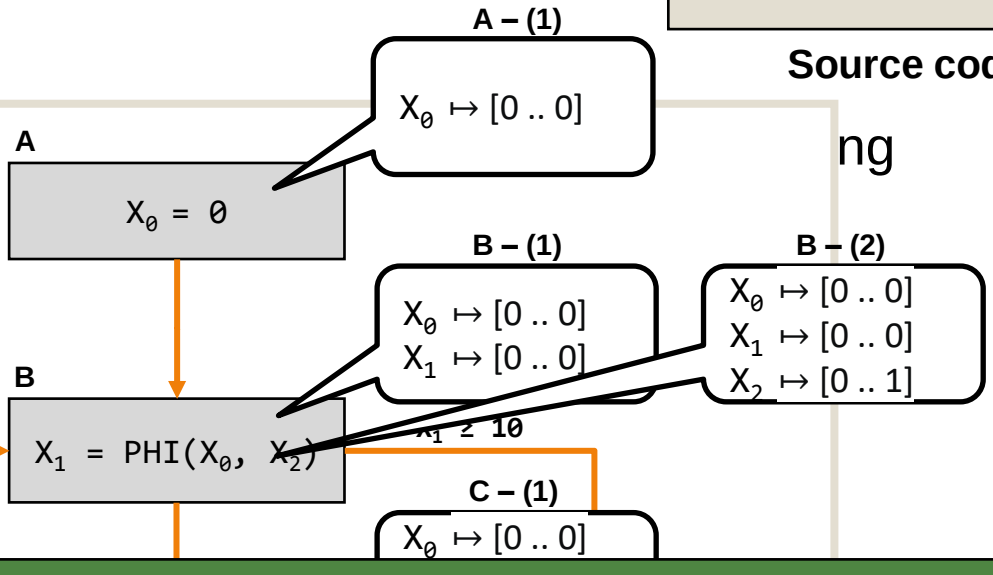

Each state is distinguished via unique identifier.

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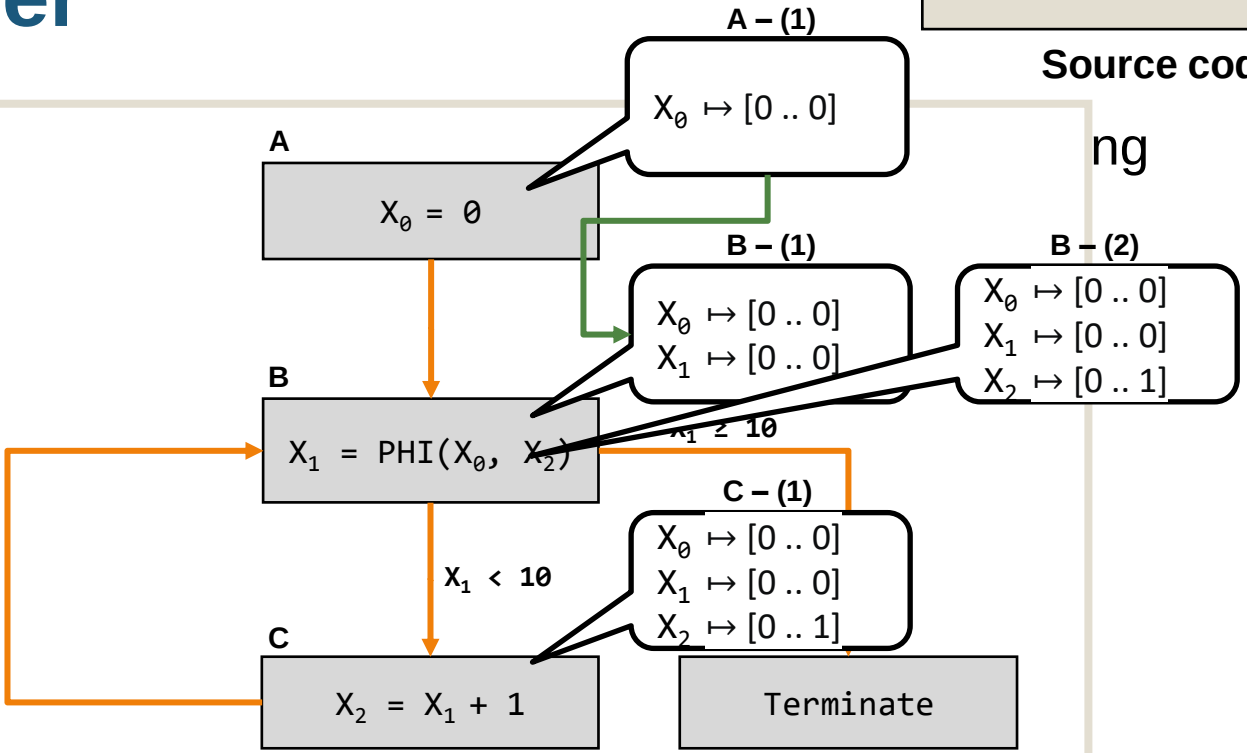

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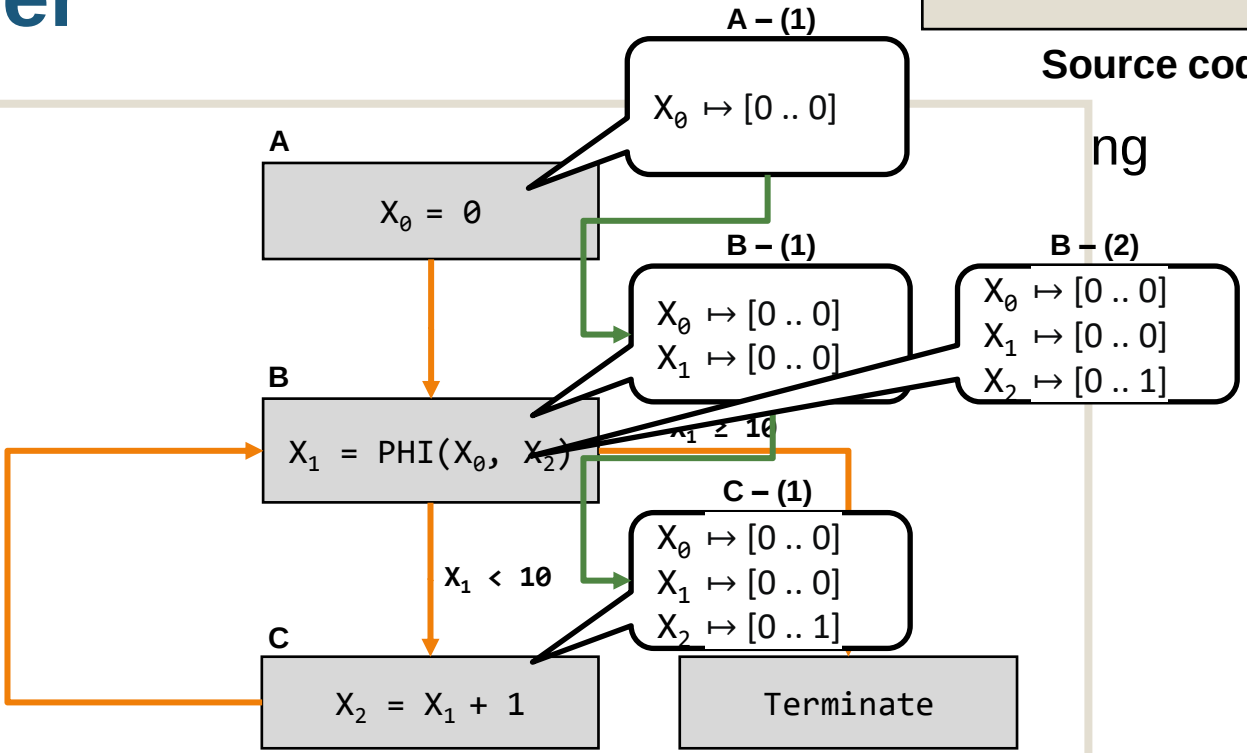

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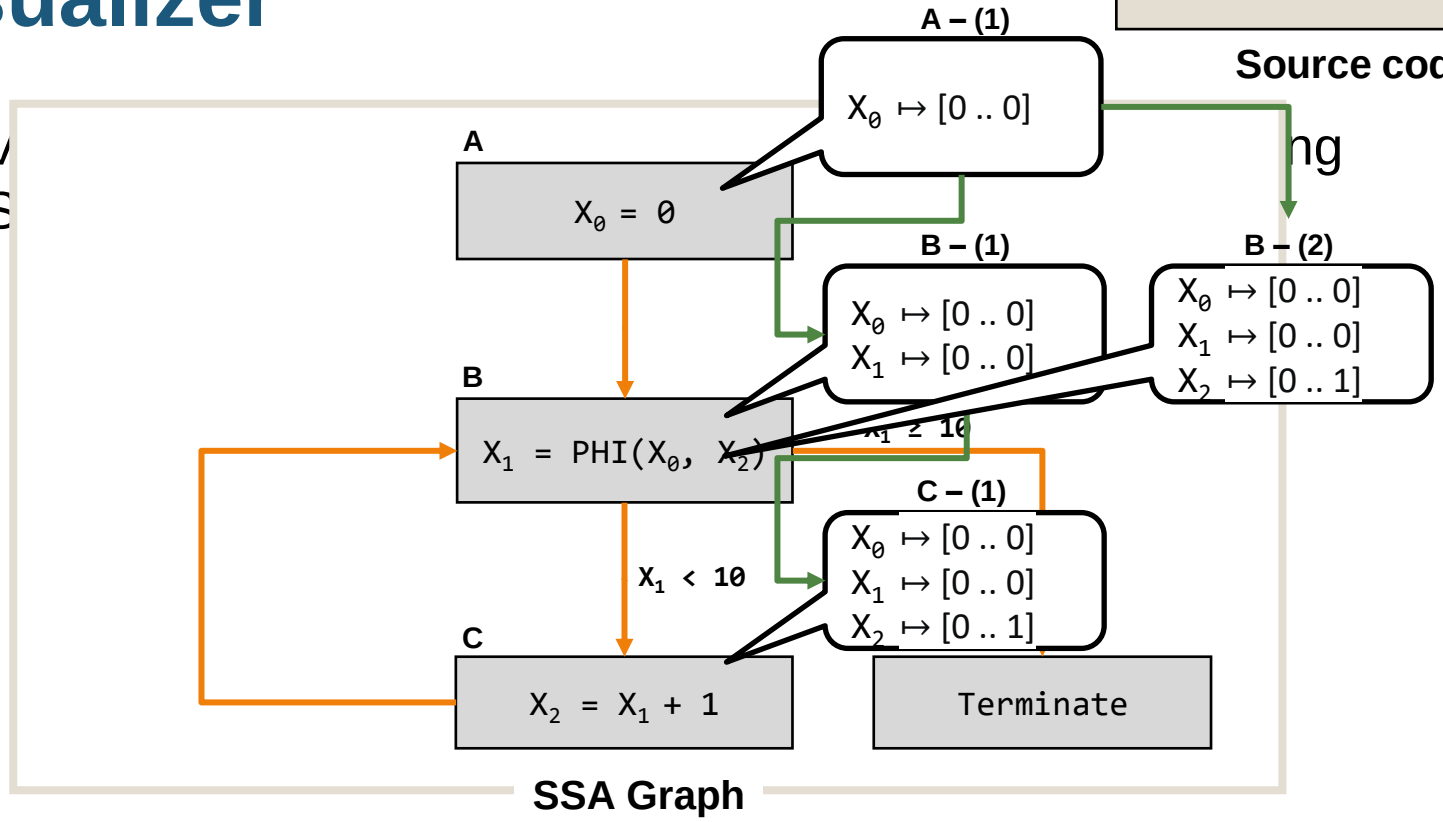

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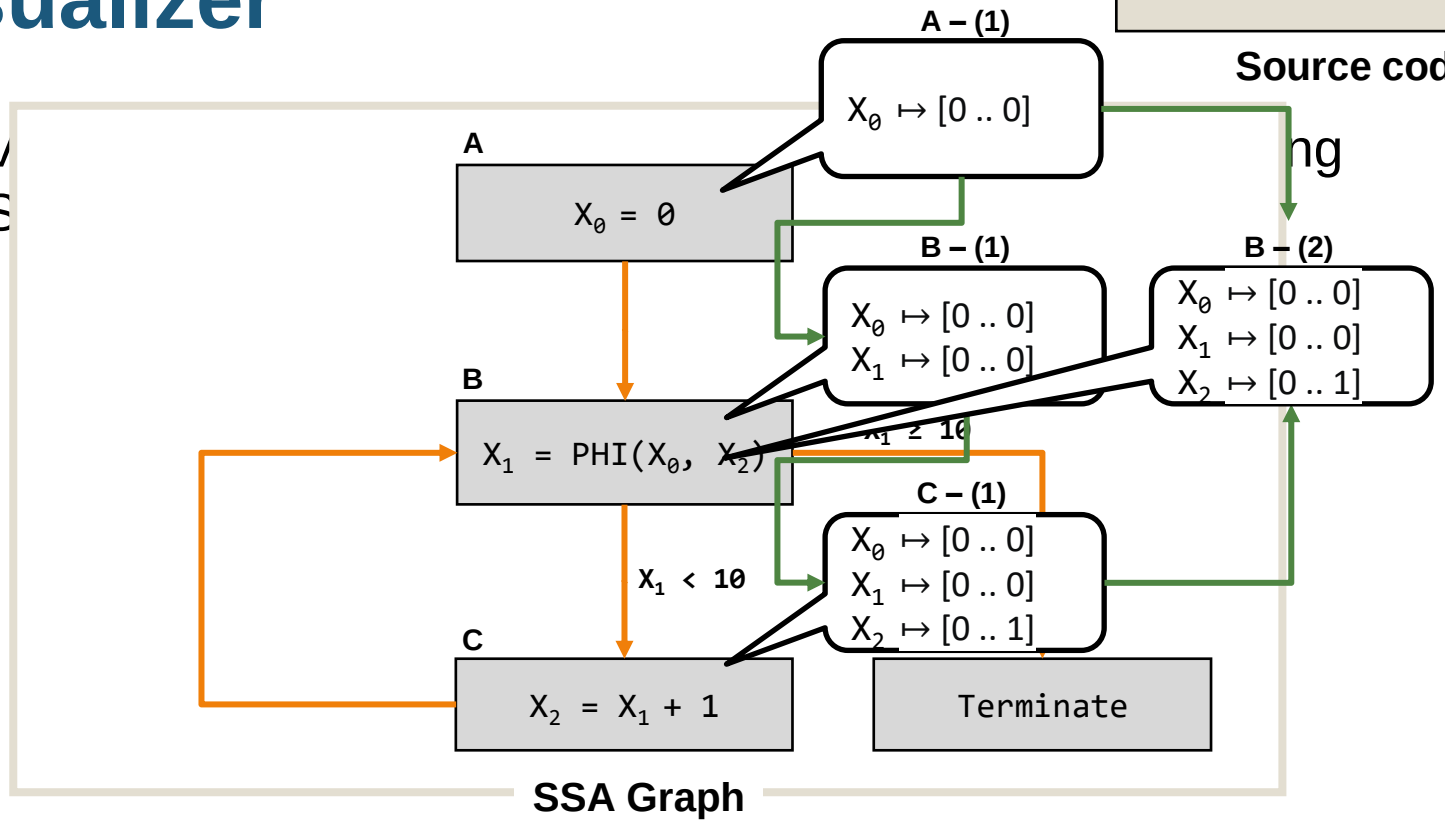

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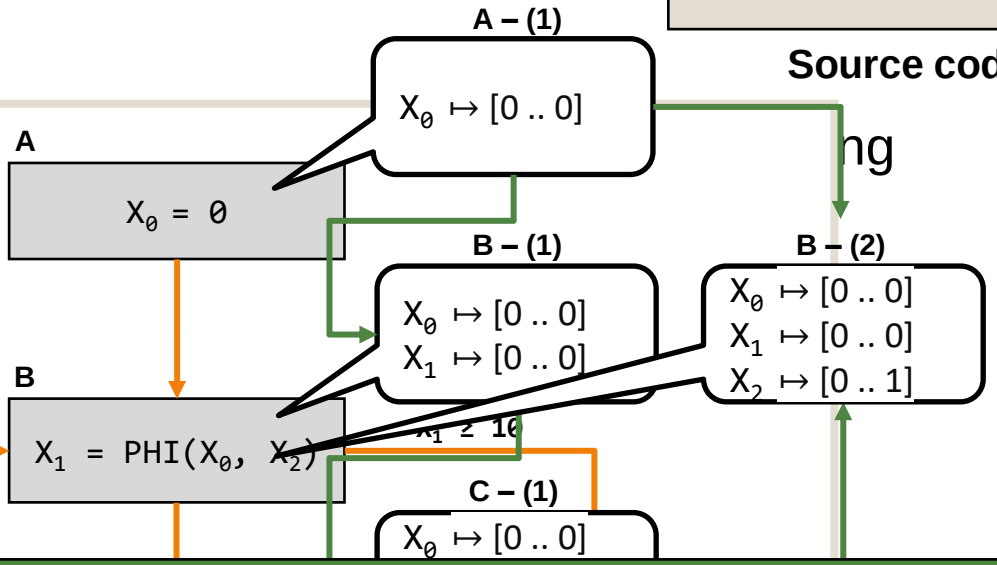

Unique identifiers help clarify the state transitions.

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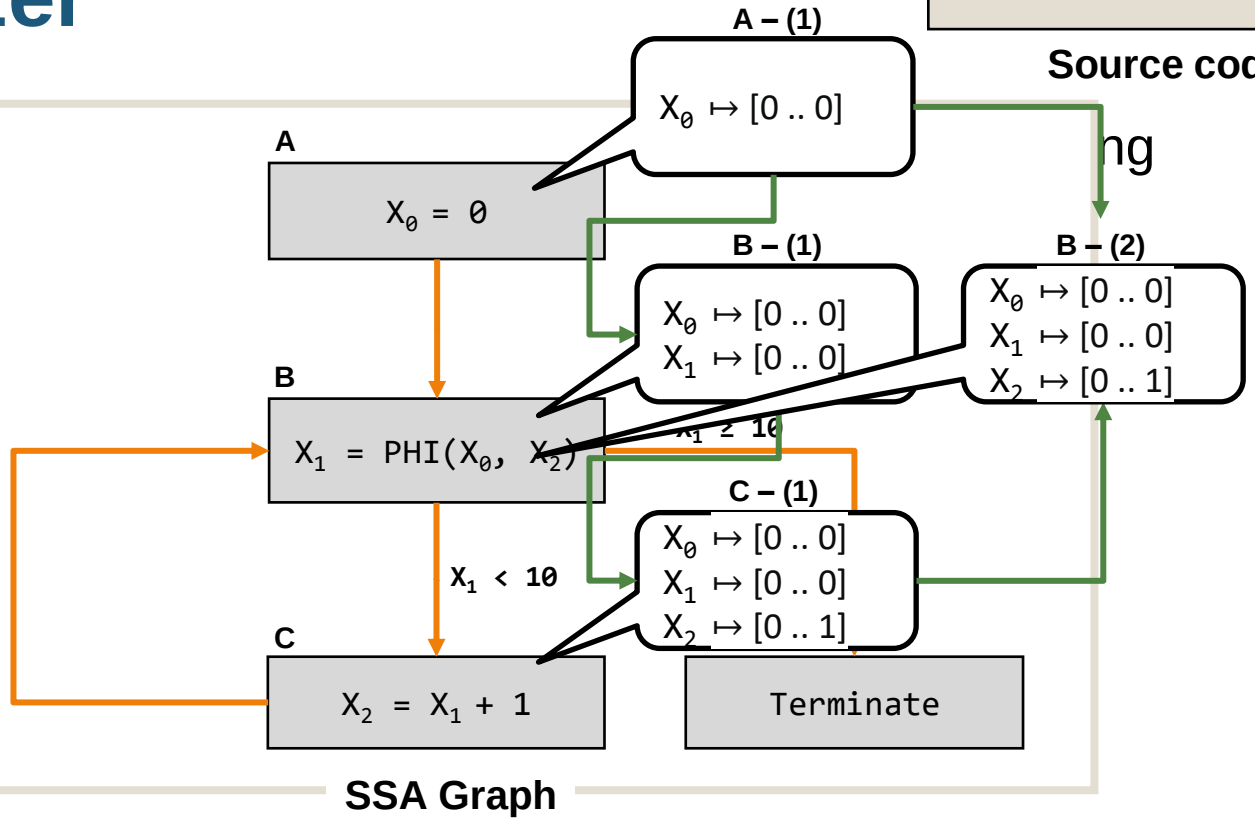

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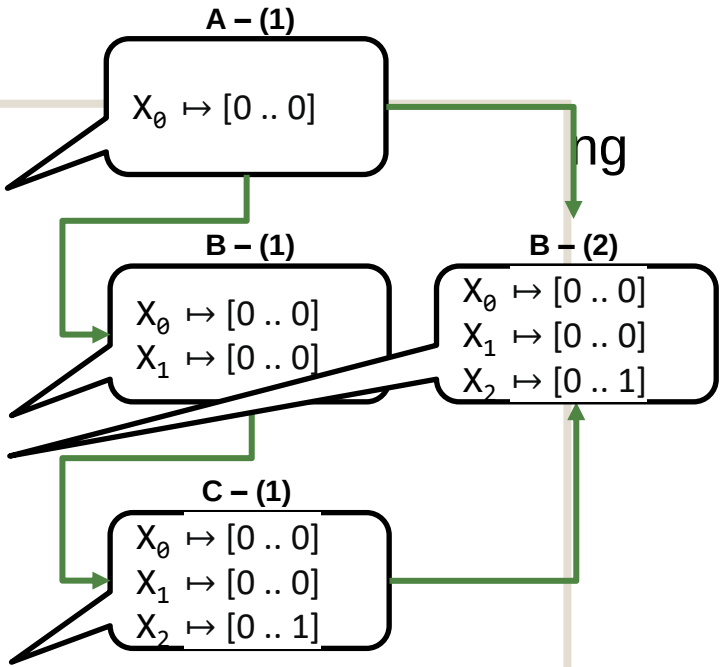

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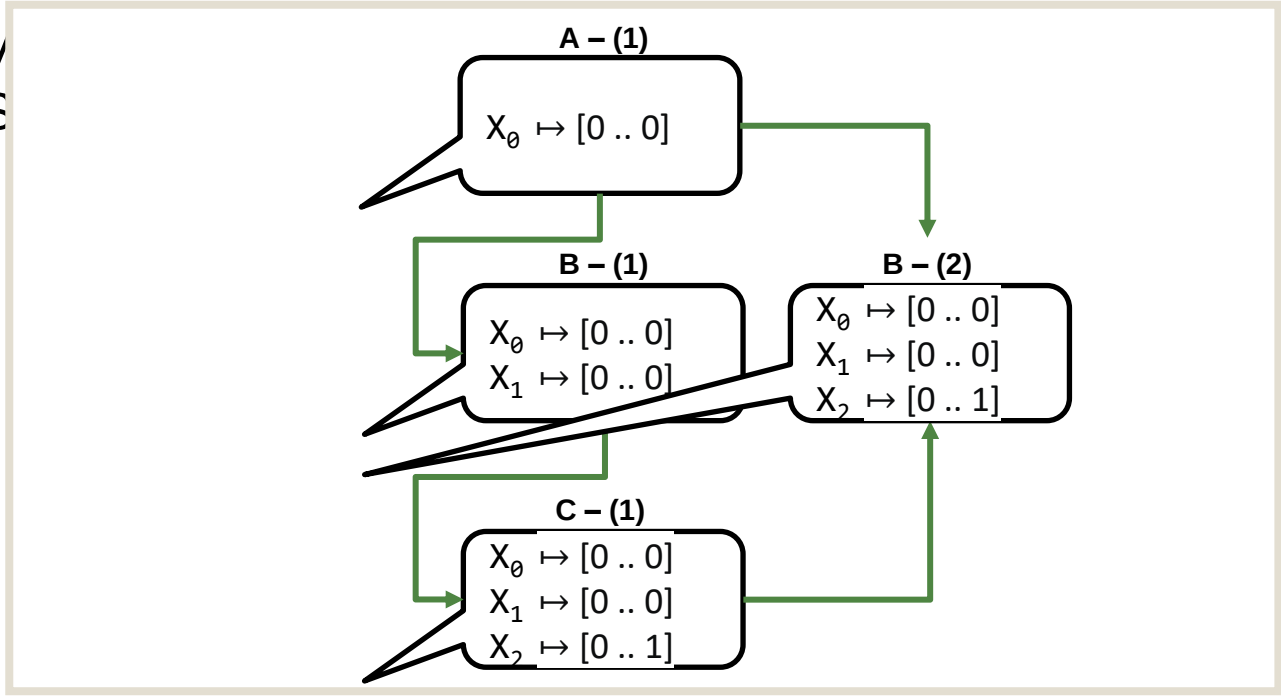

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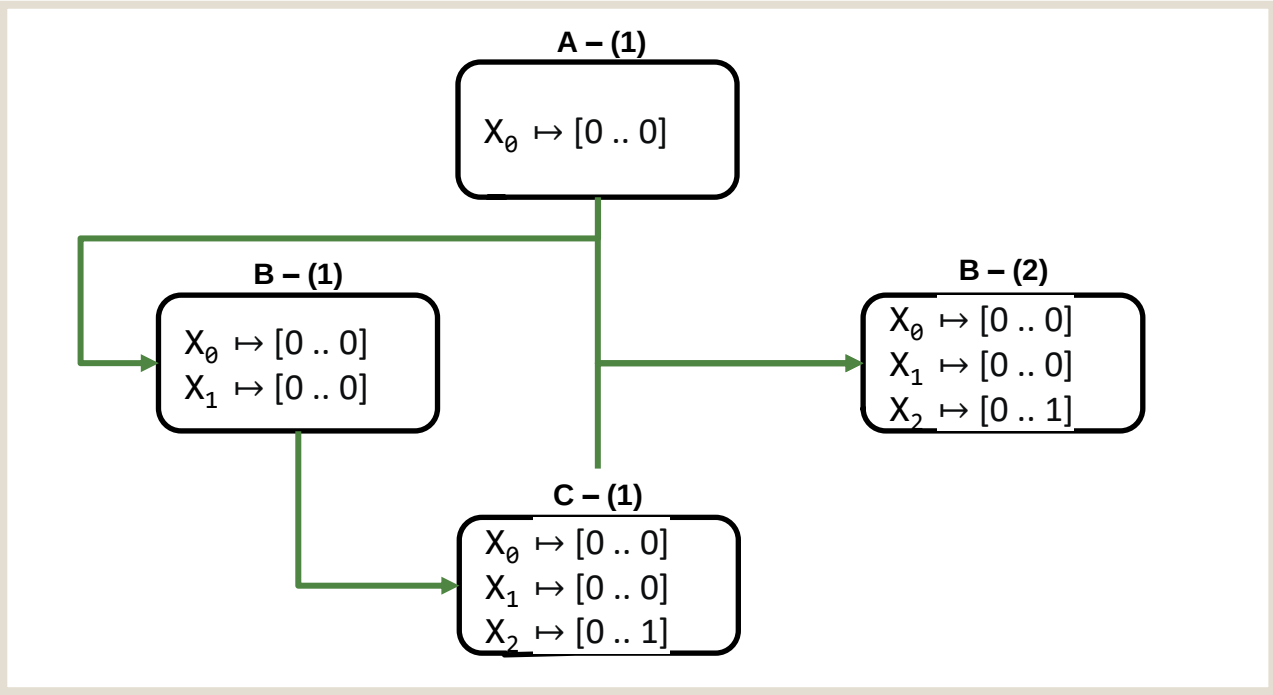
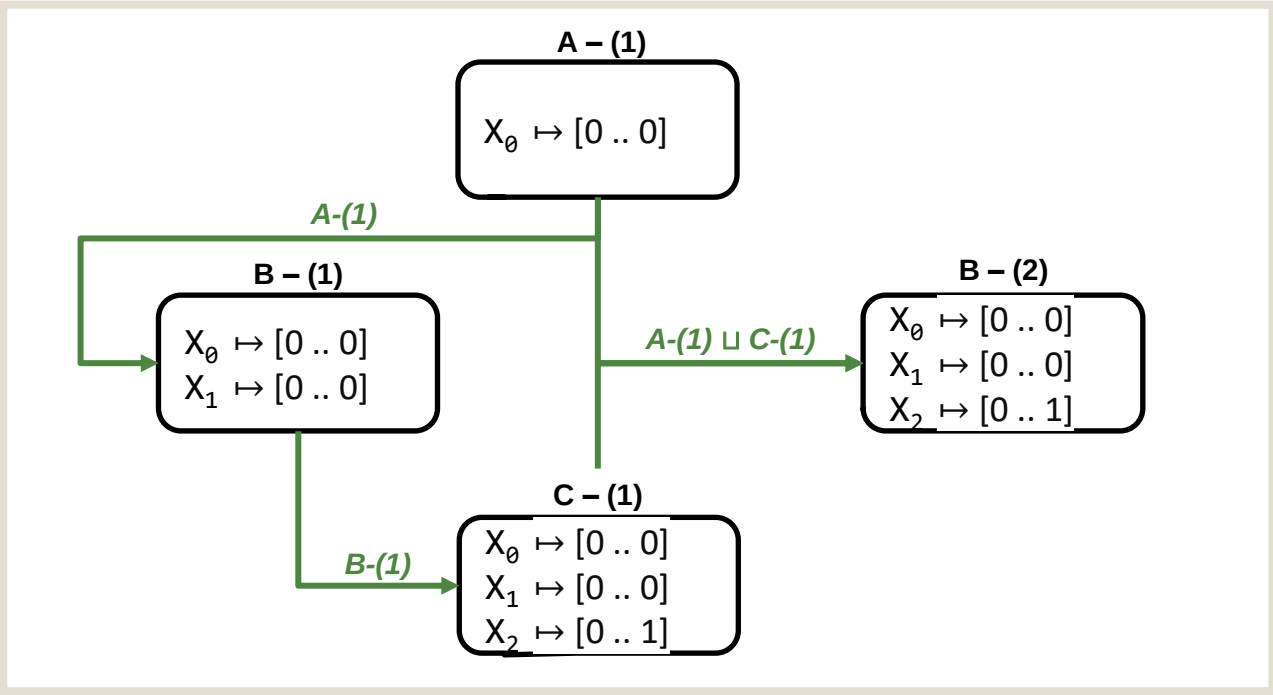


Visualizer

- V ng
  S



Visualizer

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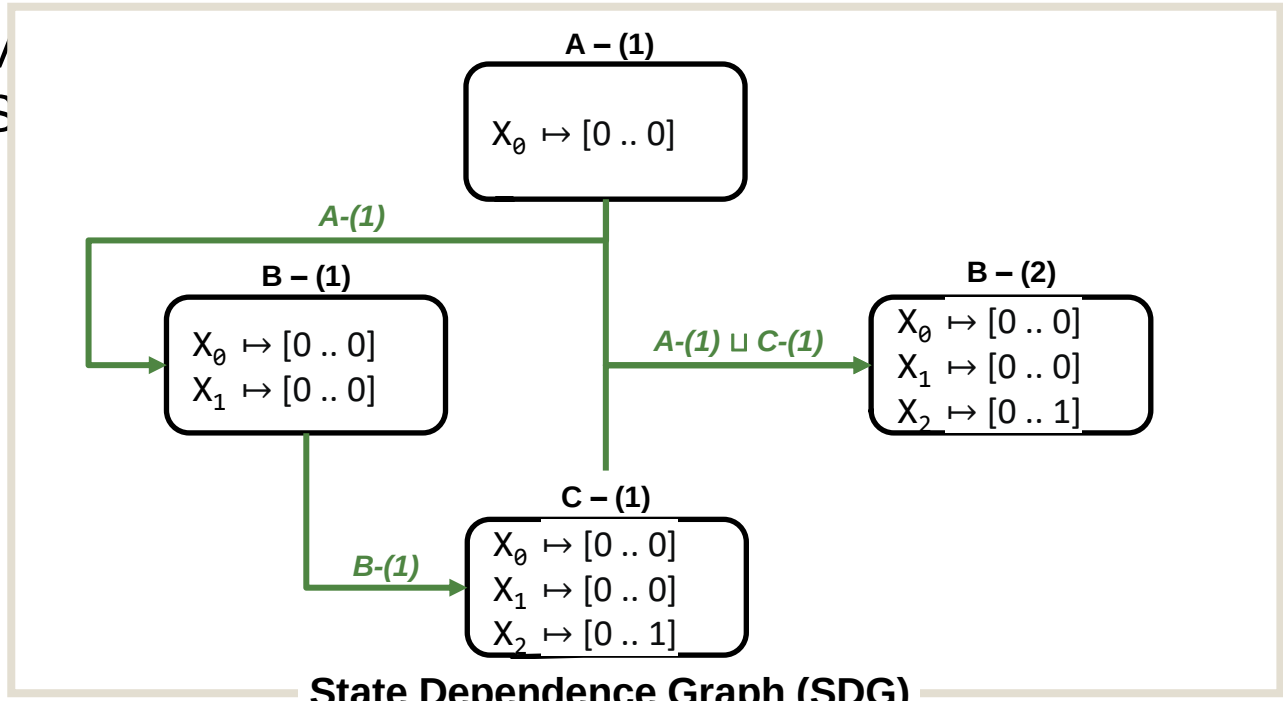
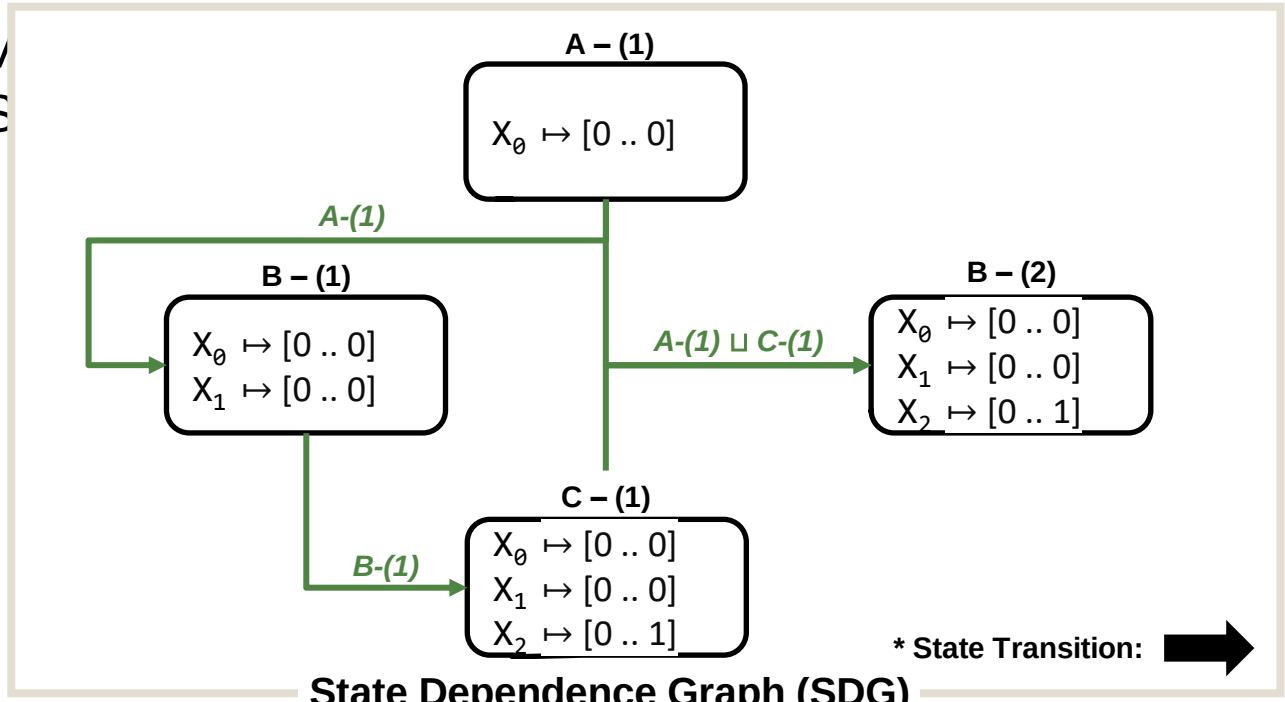


State Dependence Graph (SDG)

Visualizer

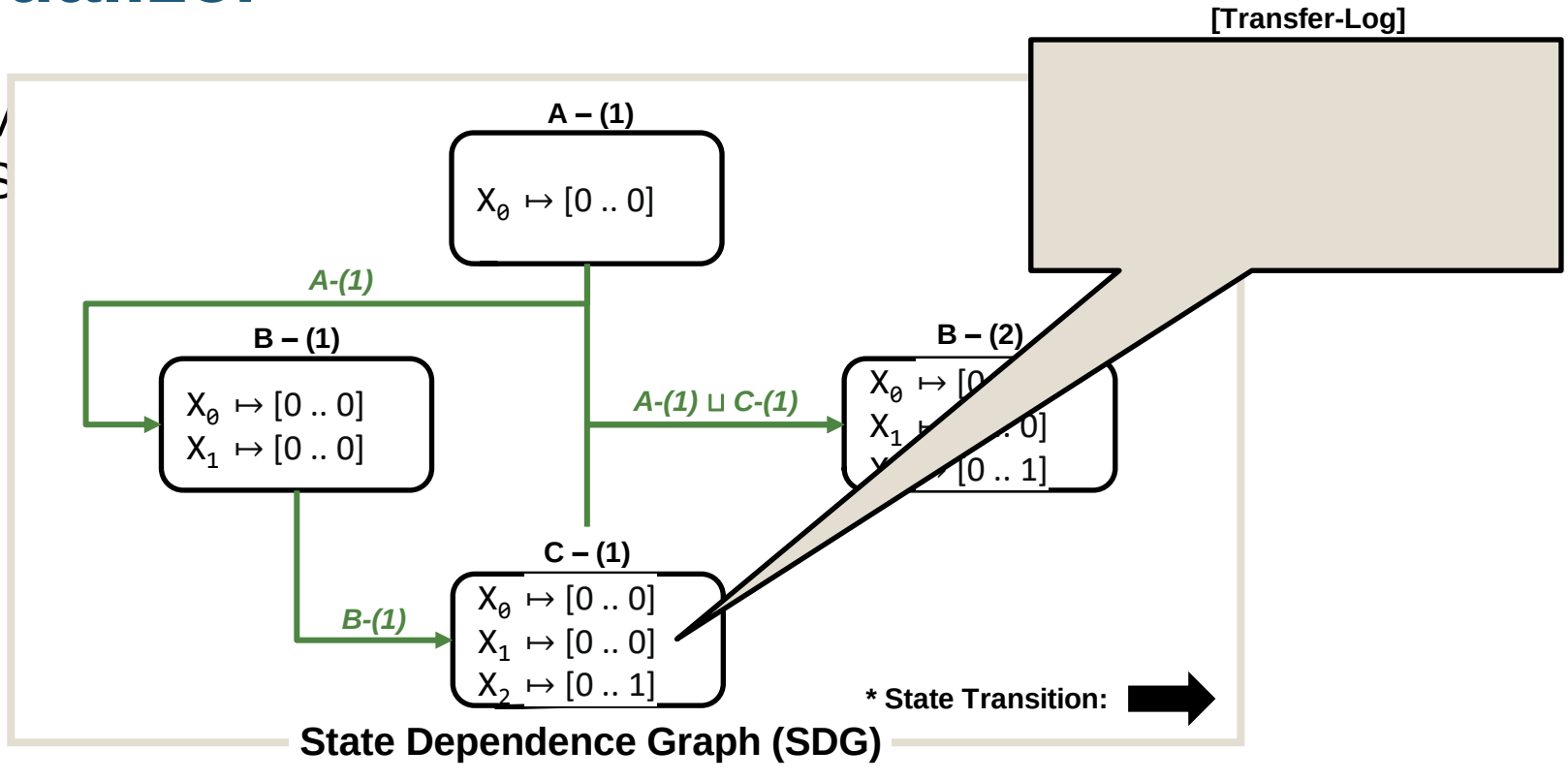
- V ng
  S



State Dependence Graph (SDG)

Visualizer

- V
  S



Visualizer

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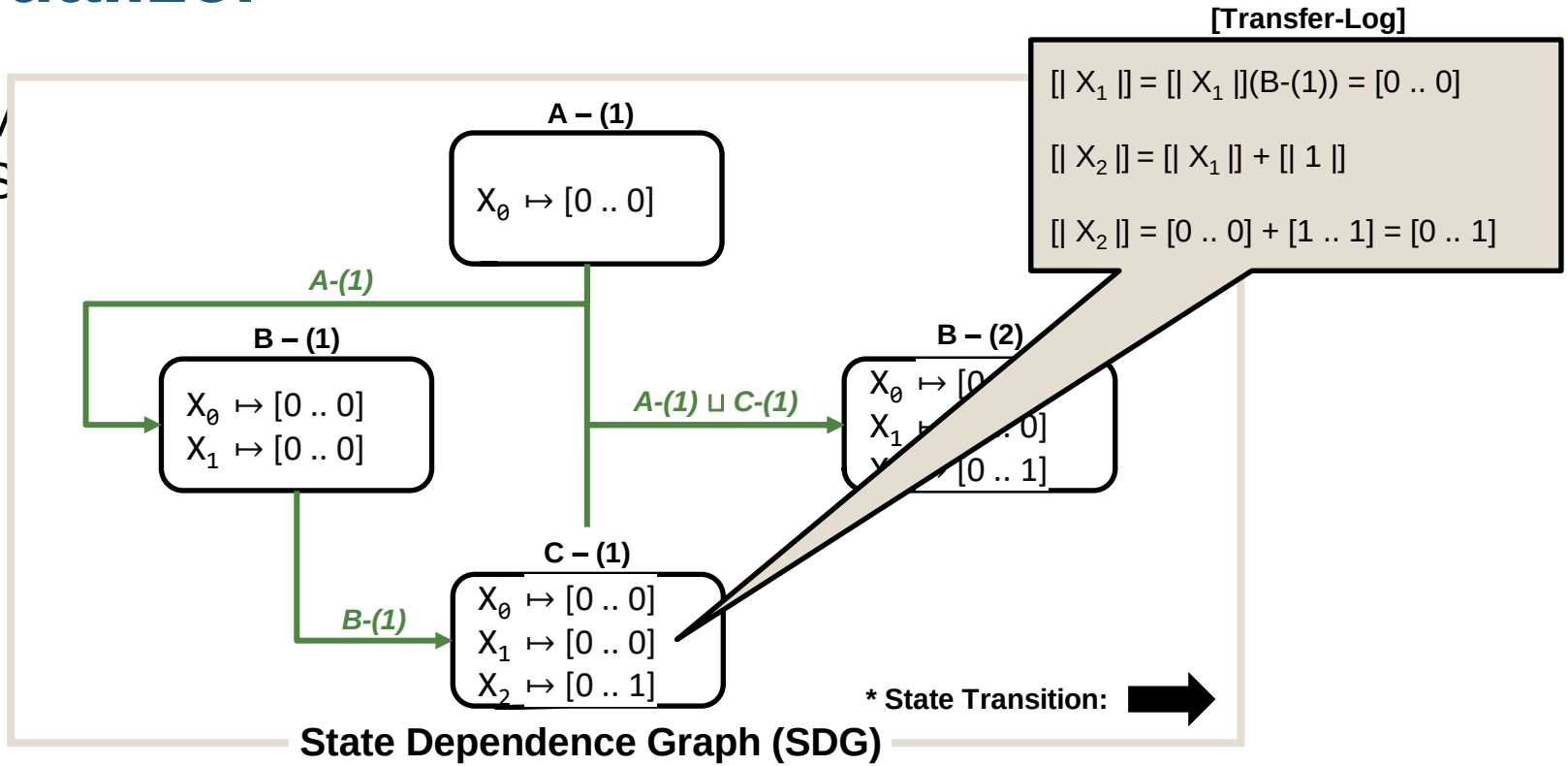
  S



Visualizer

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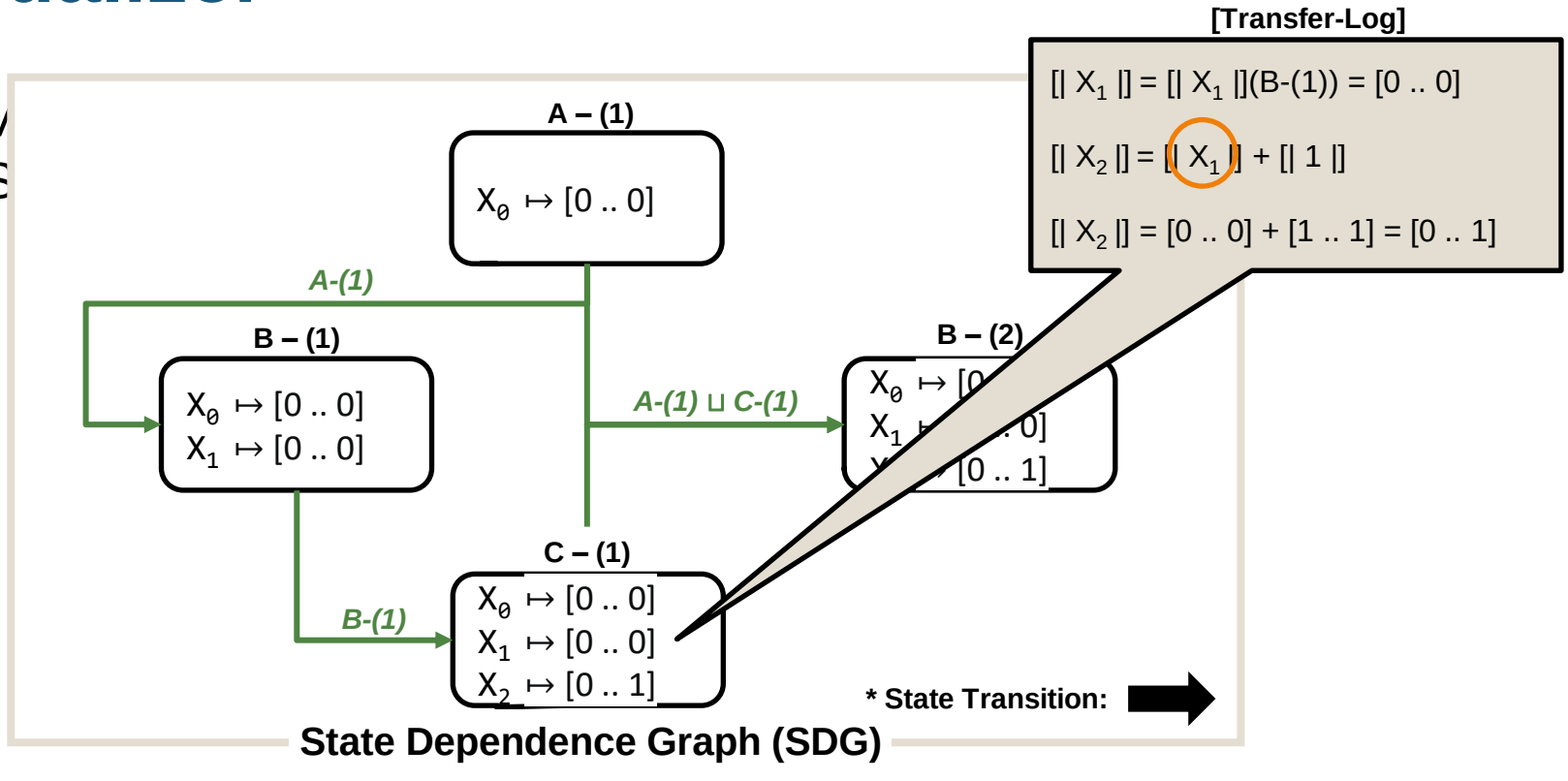

Visualizer

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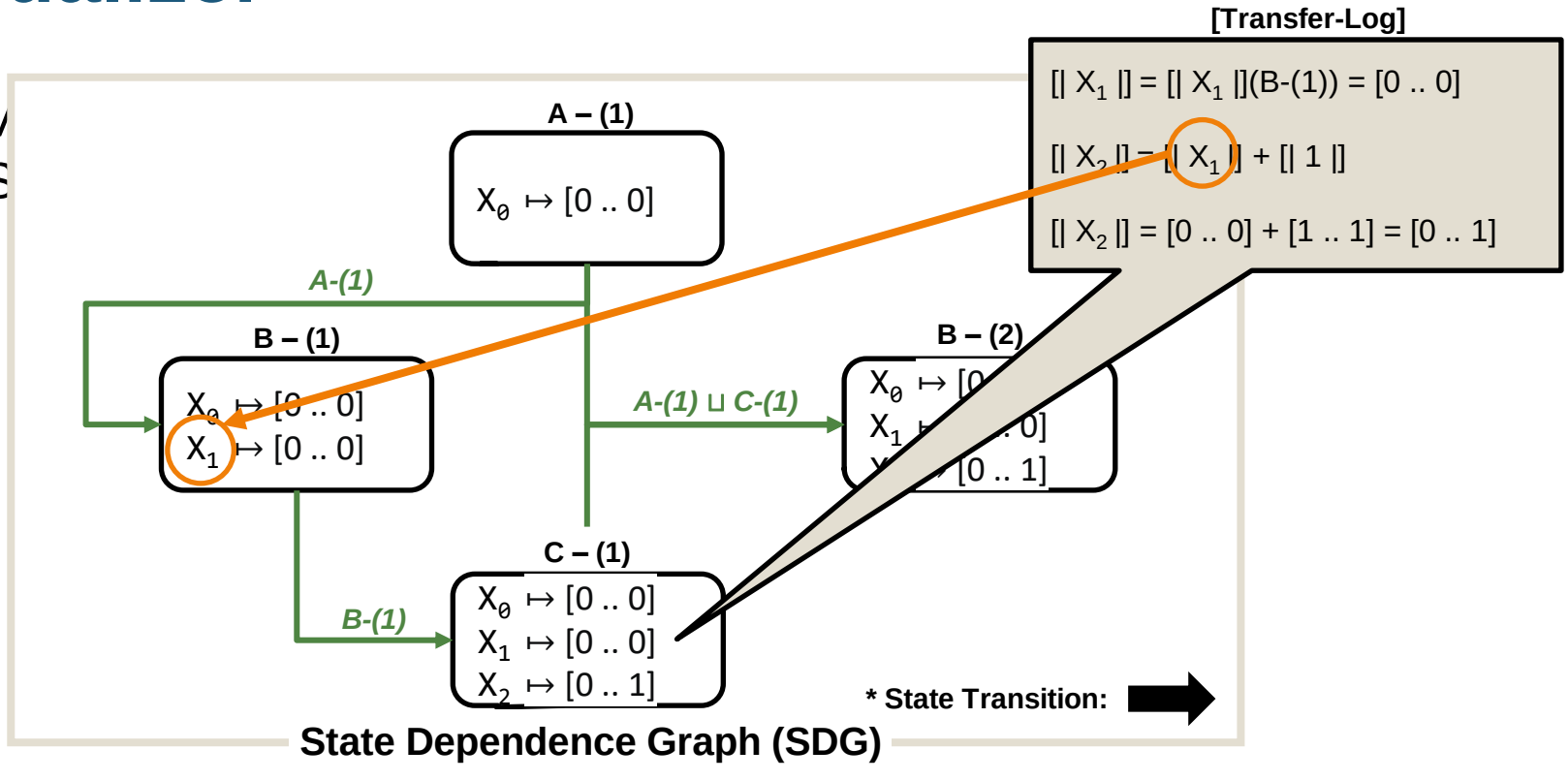
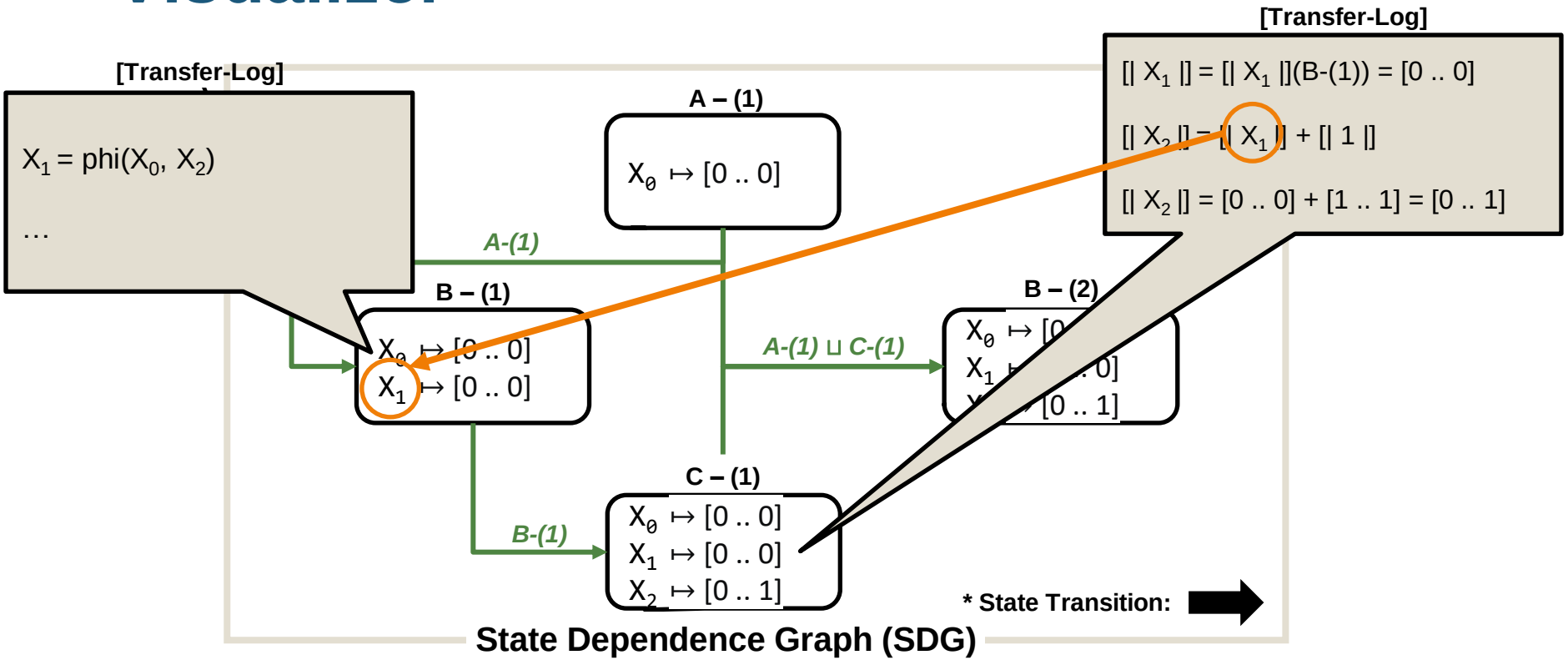
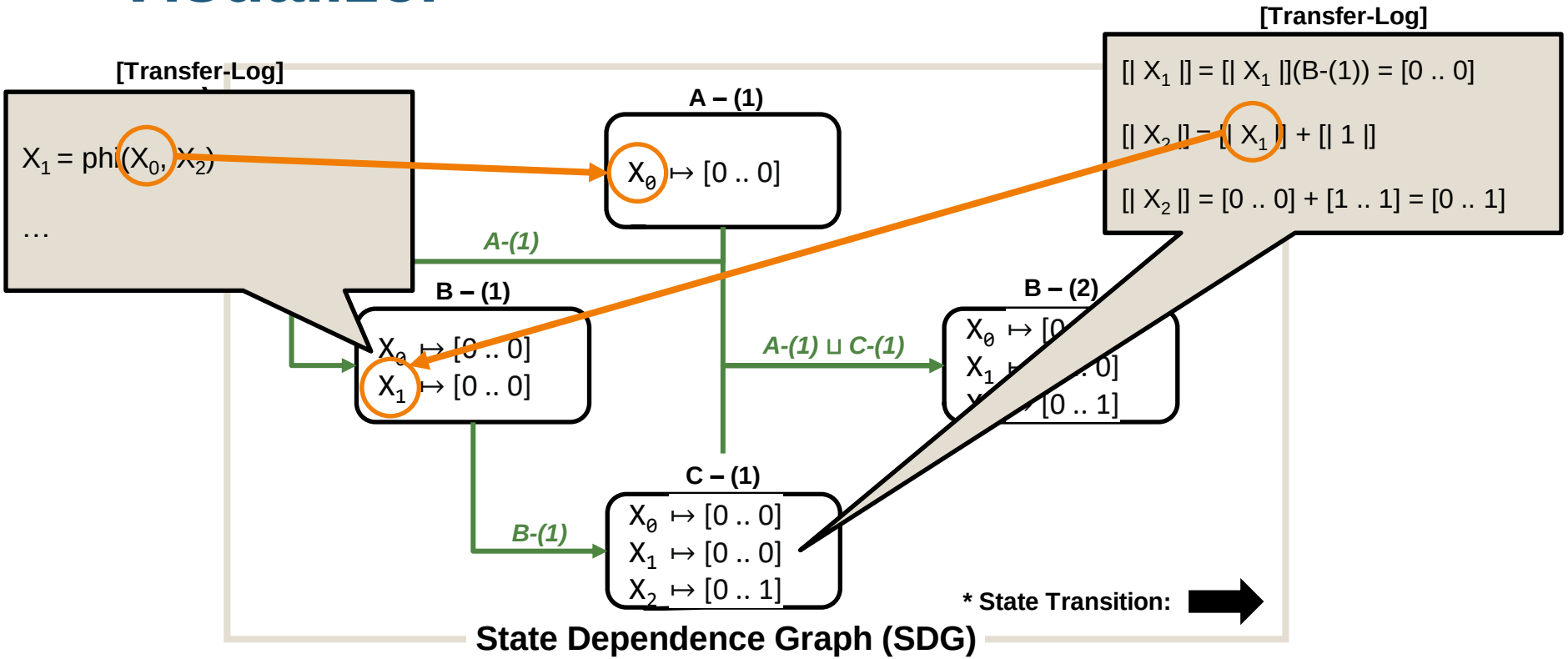


Visualizer


[Transfer-Log]
X1 = phi(X0, X2)
…
A – (1)
X0 ↦ [0 .. 0]
A-(1)
B – (1)
X0 ↦ [0 .. 0]
X1 ↦ [0 .. 0]
A-(1) ⊔ C-(1)
B – (2)
X0 ↦ [0
X1 ↦ [0 .. 0]
[0 .. 1]
B-(1)
C – (1)
X0 ↦ [0 .. 0]
X1 ↦ [0 .. 0]
X2 ↦ [0 .. 1]
[Transfer-Log]
[| X1 |] = [| X1 |](B-(1)) = [0 .. 0]
[| X2 |] = [| X1 |] + [| 1 |]
[| X2 |] = [0 .. 0] + [1 .. 1] = [0 .. 1]
* State Transition:
State Dependence Graph (SDG)

Visualizer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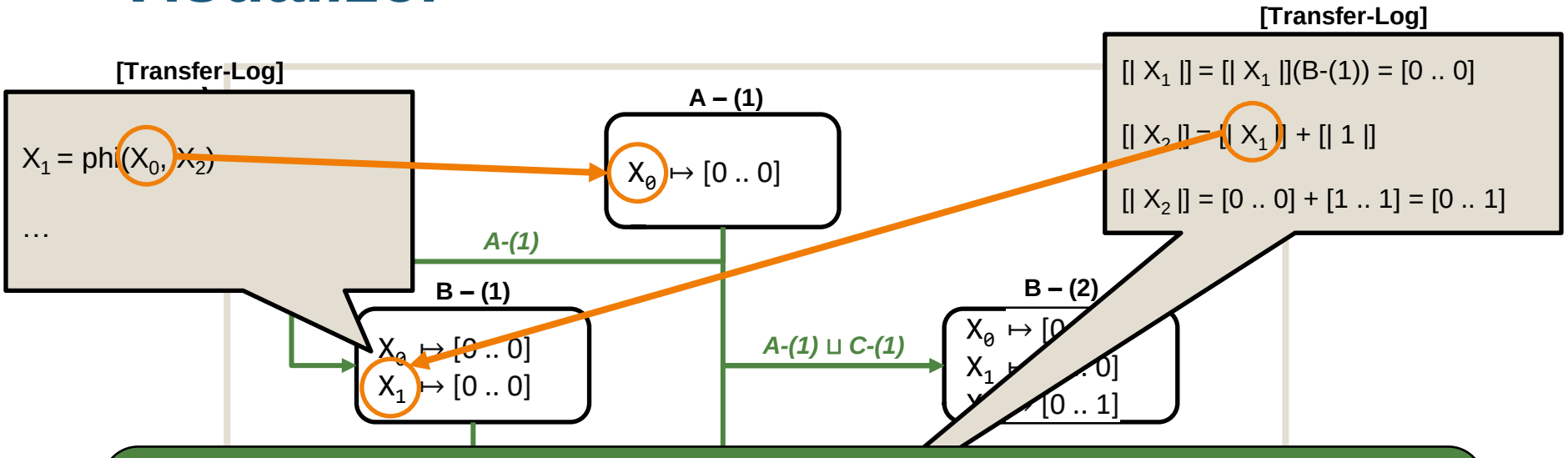

SDG helps to understand the flow of state transitions.

Visualizer

- Visualize each state that an AI process can have by using SSA Graph and State Dependence Graph (SDG).

- Sensitivities (e.g. context-sensitivity) are denoted using a prefix in a state identifier.

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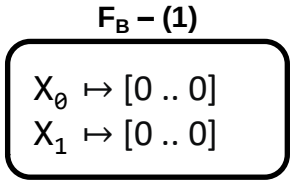

No sensitivity

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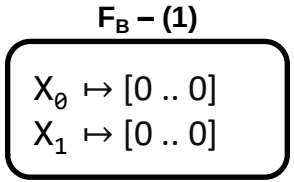

No sensitivity

Context-sensitivity w/ depth=1

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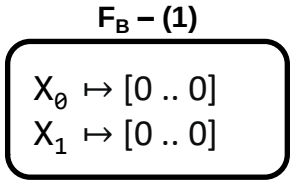
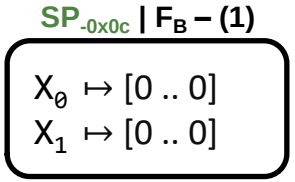


No sensitivity

Context-sensitivity w/ depth=1



Stack-pointer-sensitivity

Debugger

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- Move forward/backward between different states.

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- Set a *breakpoint* with a specific condition he wants.

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- Set a *breakpoint* with a specific condition he wants.
- Fetch the history of state transitions with *lazy evaluation*.

AI (User-Defined)

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- AI consists of three parts: *Lattice*, *Transfer Function*, and *Sensitivity*.

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- We may introduce a new DSL (Domain Specific Language) for *Lattice* and *Transfer Function*.

  → But for the prototype, we use *F#.*

Implementation

- Uses *F#* as a main programming language.
- Uses *D3.js*[2] for an interactive visualization of AI processes.
- Uses *LLVMSharp*[3] to parse/handle LLVM IR codes.

[2] Zhu, Nick Qi. Data visualization with D3. js cookbook. Packt Publishing Ltd, 2013.
[3] LLVMSharp, https://github.com/dotnet/LLVMSharp, 2024.

Objectives

- To help students learn AI.
- To help researchers analyze their AI.
- To be a popular framework that is widely-used by people.
- To be integrated into frameworks that internally use AI.

Request For Funding

- Salary for one PhD student & one Master student:
  $3,000 × 2 per month
- Three workstations for development and evaluation of our work:
  $5,000 × 3

Our Plan

- We will finish our prototype until this June.
- We will integrate our prototype into *B2R2*[4] until this August.
- We will finish and commercialize our project until this December.

[4] B2R2, https://github.com/B2R2-org/B2R2, 2024.

Question?