

Exam Questions

TEACHING ASSISTANT: DAVID TRABISH

Question

The program contains a string constant.

compiler construction

compiling

runtime

Question

The program contains a string constant.

compiler construction

compiling

runtime

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Every time the command $x = y + 42$ is executed, the value of y is 0.

compiler construction

compiling

runtime

Question

Every time the command $x = y + 42$ is executed, the value of y is 0.

compiler construction

compiling

runtime

Question

All the variable names start with *x*.

compiler construction

compiling

runtime

Question

All the variable names start with x.

compiler construction

compiling

runtime

Question

The program contains a nested loop.

compiler construction

compiling

runtime

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The program contains a nested loop.

compiler construction

compiling

runtime

Question

The program contains a string constant with at least 200 characters.

compiler construction

compiling

runtime

Question

The program contains a string constant with at least 200 characters.

compiler construction

compiling

runtime

Question

The size of the stack exceeds 400 bytes.

compiler construction

compiling

runtime

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compiler construction

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Question

There is an addition operation which is never executed in any run.

compiler construction

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Question

There is an addition operation which is never executed in any run.

compiler construction

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runtime

LR(0) Item

An LR(0) item with the dot at the end is called **reduce** item:

- $N \rightarrow \alpha\beta.$

Otherwise, it's a **shift** item:

- $N \rightarrow .\alpha\beta$
- $N \rightarrow \alpha.\beta$

LR(0) Item Closure Set

The LR(0) closure set of an LR(0) item i is a set S such that:

- $i \in S$
- If $A \rightarrow \alpha.N\beta \in S$ then for each rule $N \rightarrow \gamma$:
 - $N \rightarrow.\gamma \in S$

SLR(1)

- Same push-down automaton as in LR(0)
- But reduce items has a look-ahead set
 - $A \rightarrow \alpha. \{t_1, t_2, \dots\}$
 - where $Follow(A) = \{t_1, t_2, \dots\}$

LR(1)

An LR(1) item is of the form:

- $N \rightarrow \alpha.\beta \{\sigma\}$
- where $\sigma = t_1, t_2, \dots$ (terminals)

LR(1) Item Closure Set

The **LR(1) closure set** of an LR(1) item i is a set S such that:

- $i \in S$
- If $A \rightarrow \alpha.N\beta \{ \sigma \} \in S$ then for each rule $N \rightarrow \gamma$:
 - $N \rightarrow .\gamma \{ \tau \} \in S$, where $\tau = First(\beta, \{ \sigma \})$

Definition for $First(\beta, \{ \sigma \})$:

- If β is not nullable:
 - $First(\beta)$
- Otherwise:
 - $(First(\beta) \cup \{ \sigma \}) \setminus \{ \epsilon \}$

Question

Is the following CFG LR(0) / SLR(1) / LR(1)?

- $S \rightarrow A\$$
- $A \rightarrow Axx$
- $A \rightarrow x$

s_0 :

$S \rightarrow .A\$$

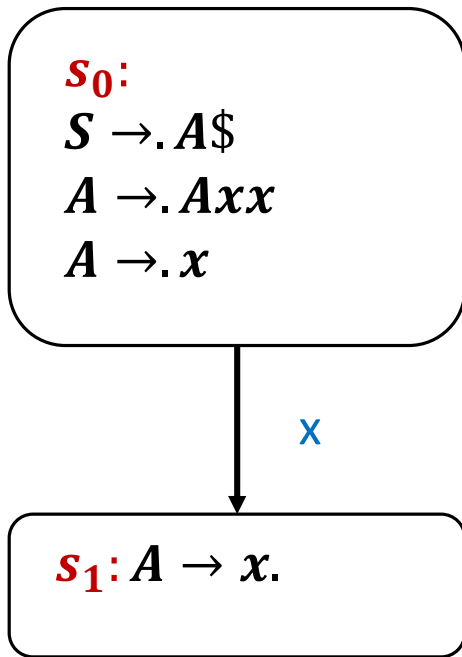
$A \rightarrow .Axx$

$A \rightarrow .x$

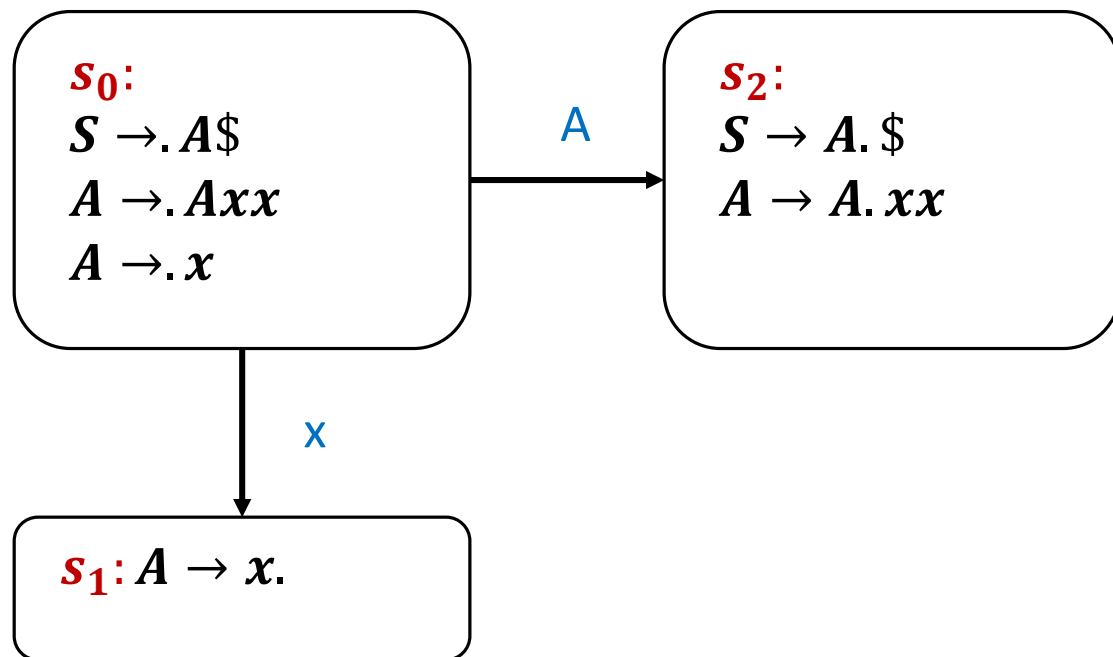
$S \rightarrow A\$$

$A \rightarrow Axx$

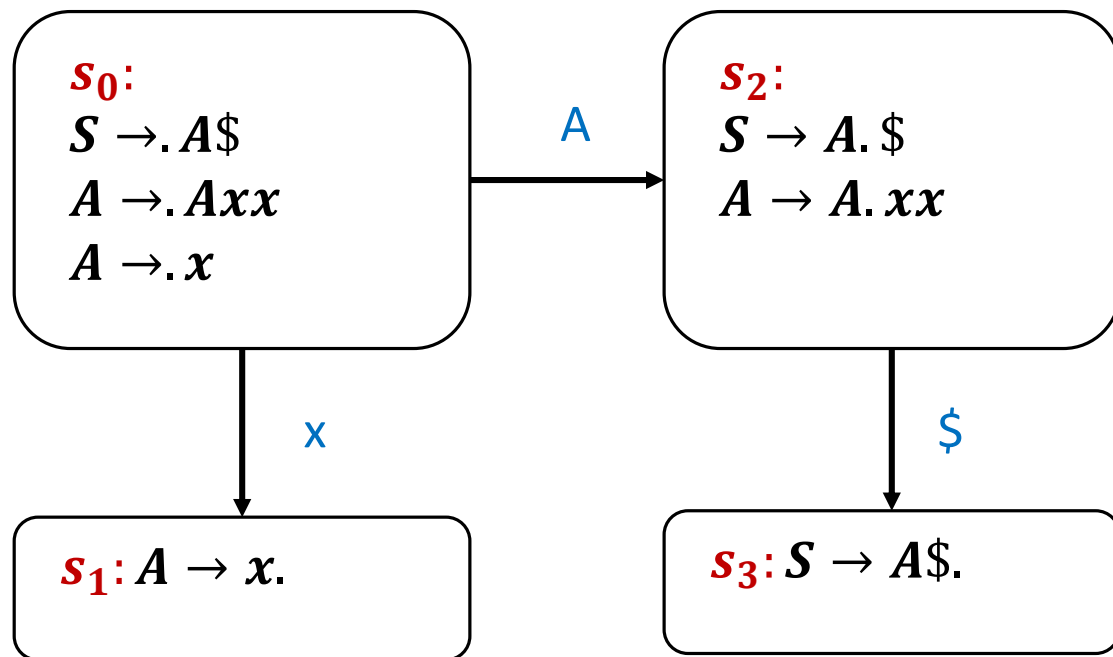
$A \rightarrow x$



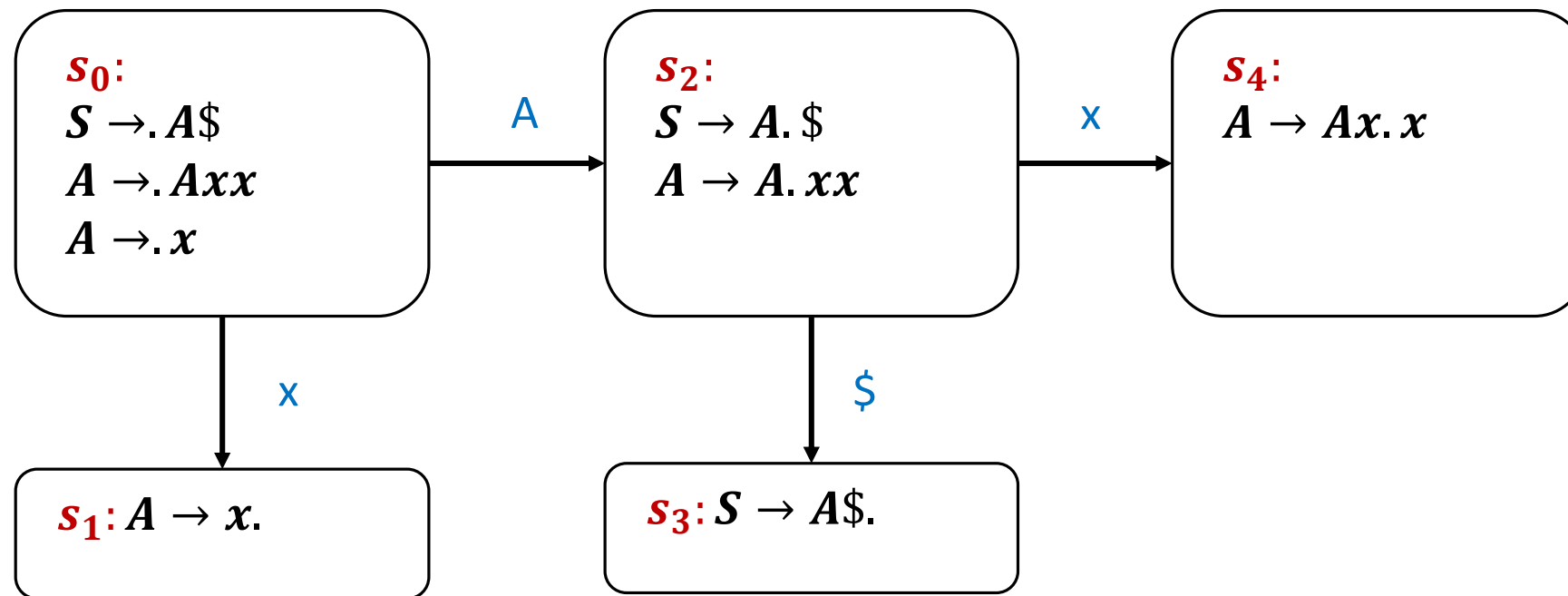
$S \rightarrow A\$$
 $A \rightarrow Axx$
 $A \rightarrow x$



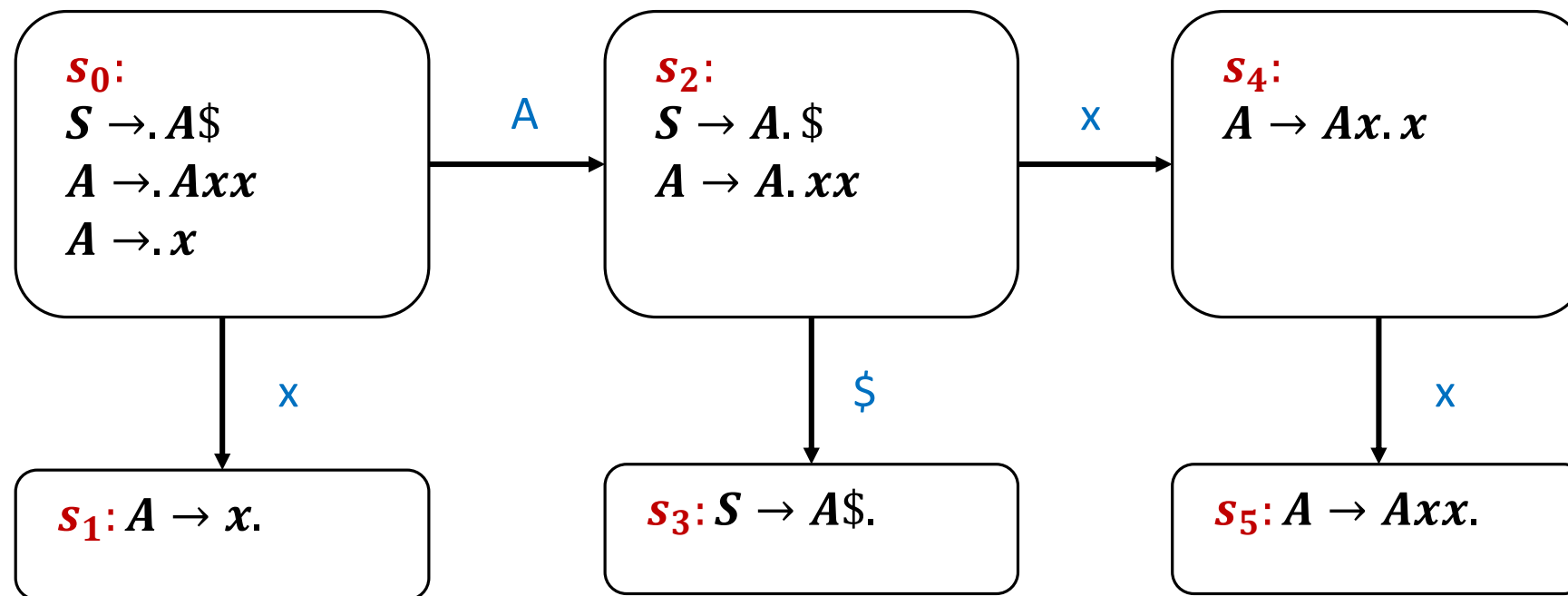
$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$

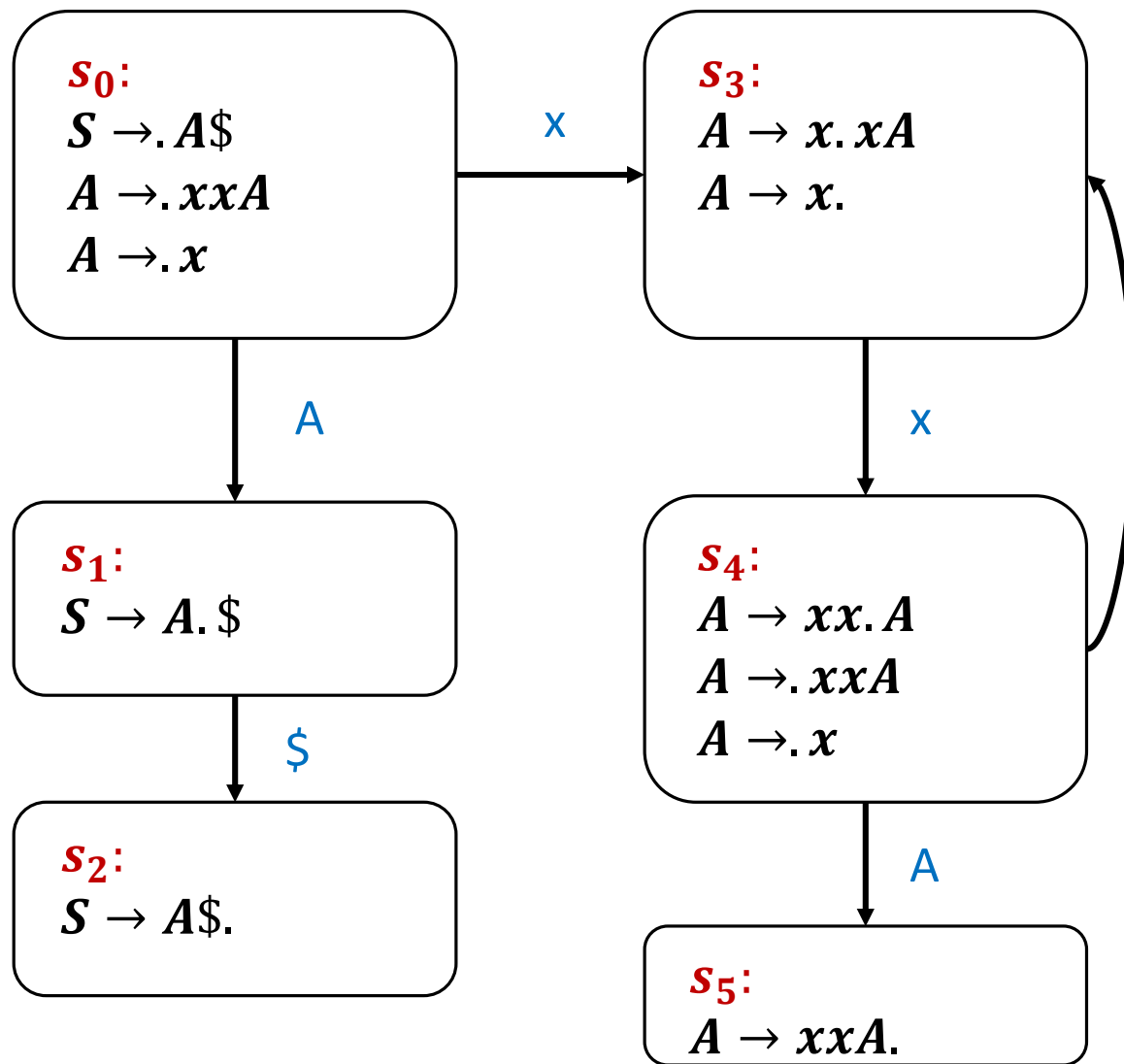


$S \rightarrow A \$$
 $A \rightarrow A x x$
 $A \rightarrow x$

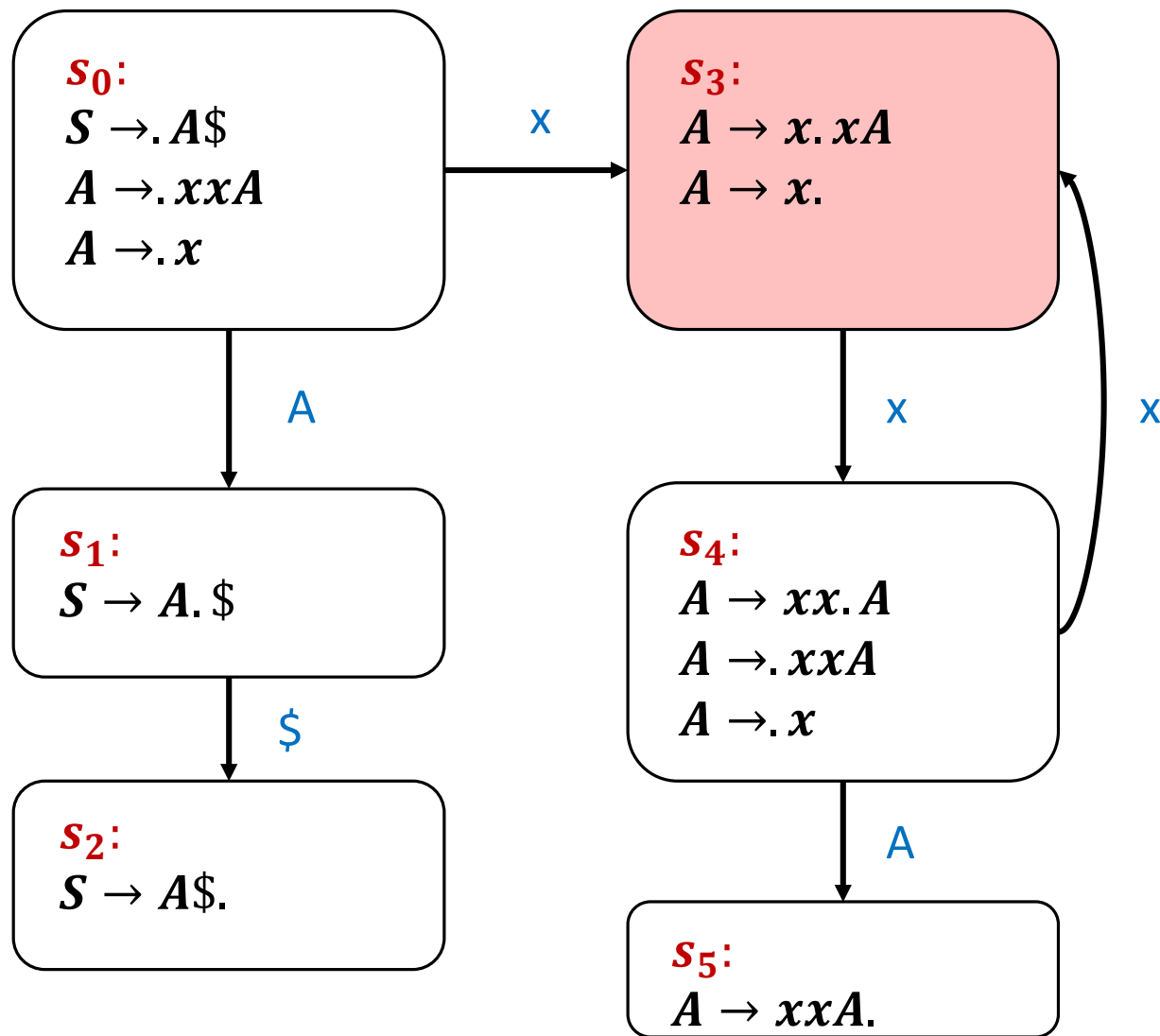
Question

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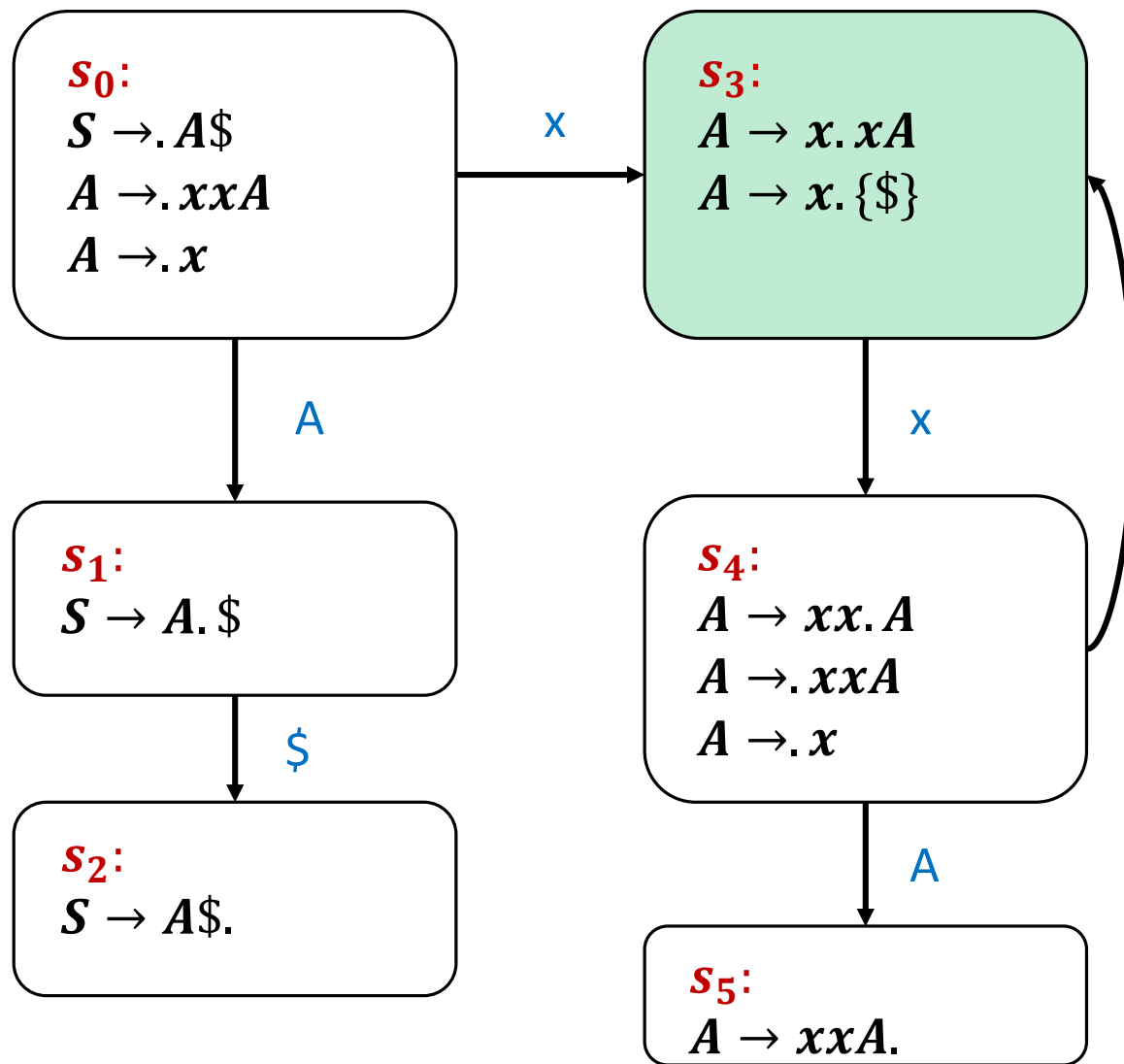
- $S \rightarrow A\$$
- $A \rightarrow xxA$
- $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x x A$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow xx A$
 $A \rightarrow x$



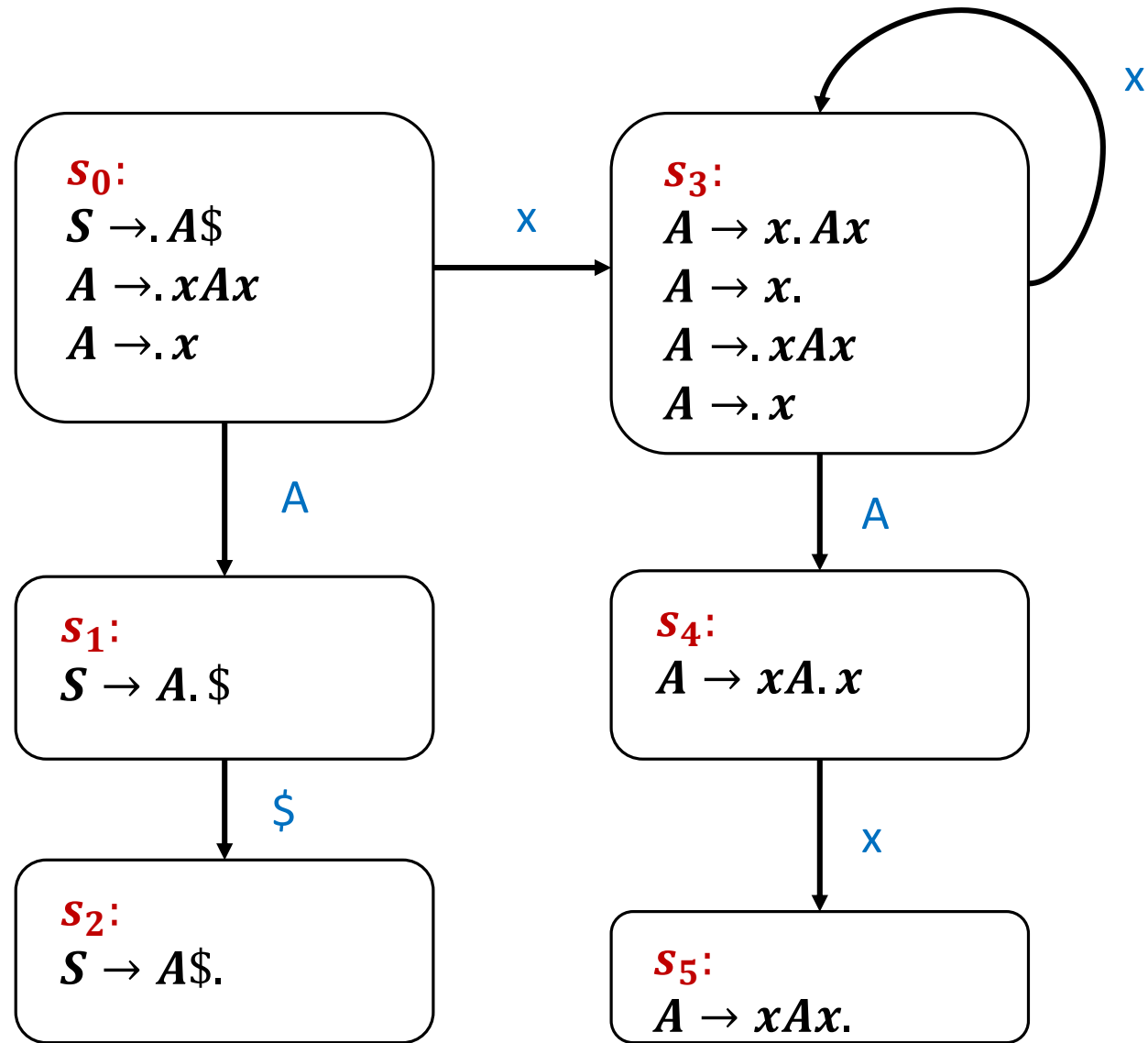
$$\text{Follow}(A) = \{ \$ \}$$

$S \rightarrow A \$$
 $A \rightarrow x x A$
 $A \rightarrow x$

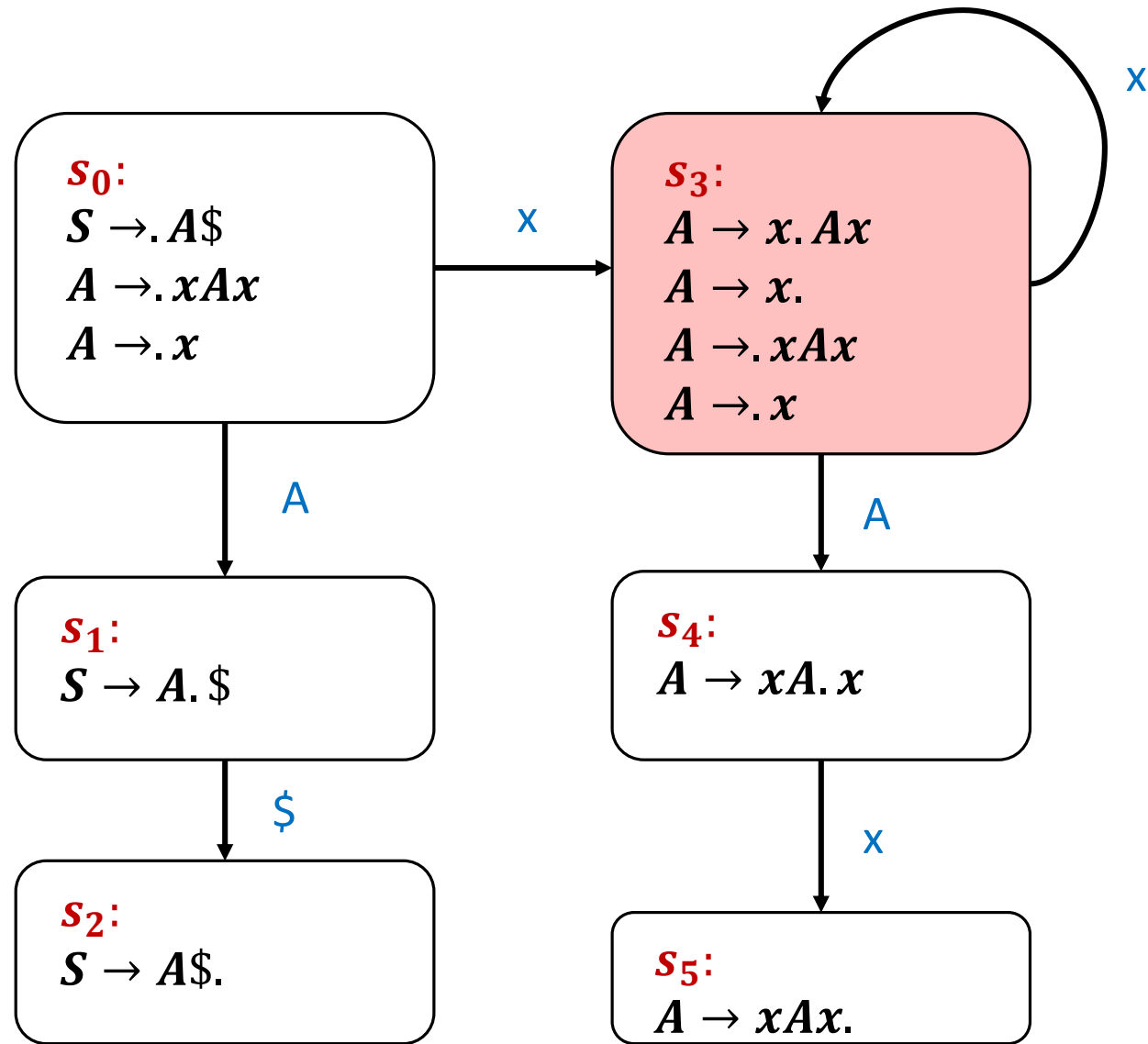
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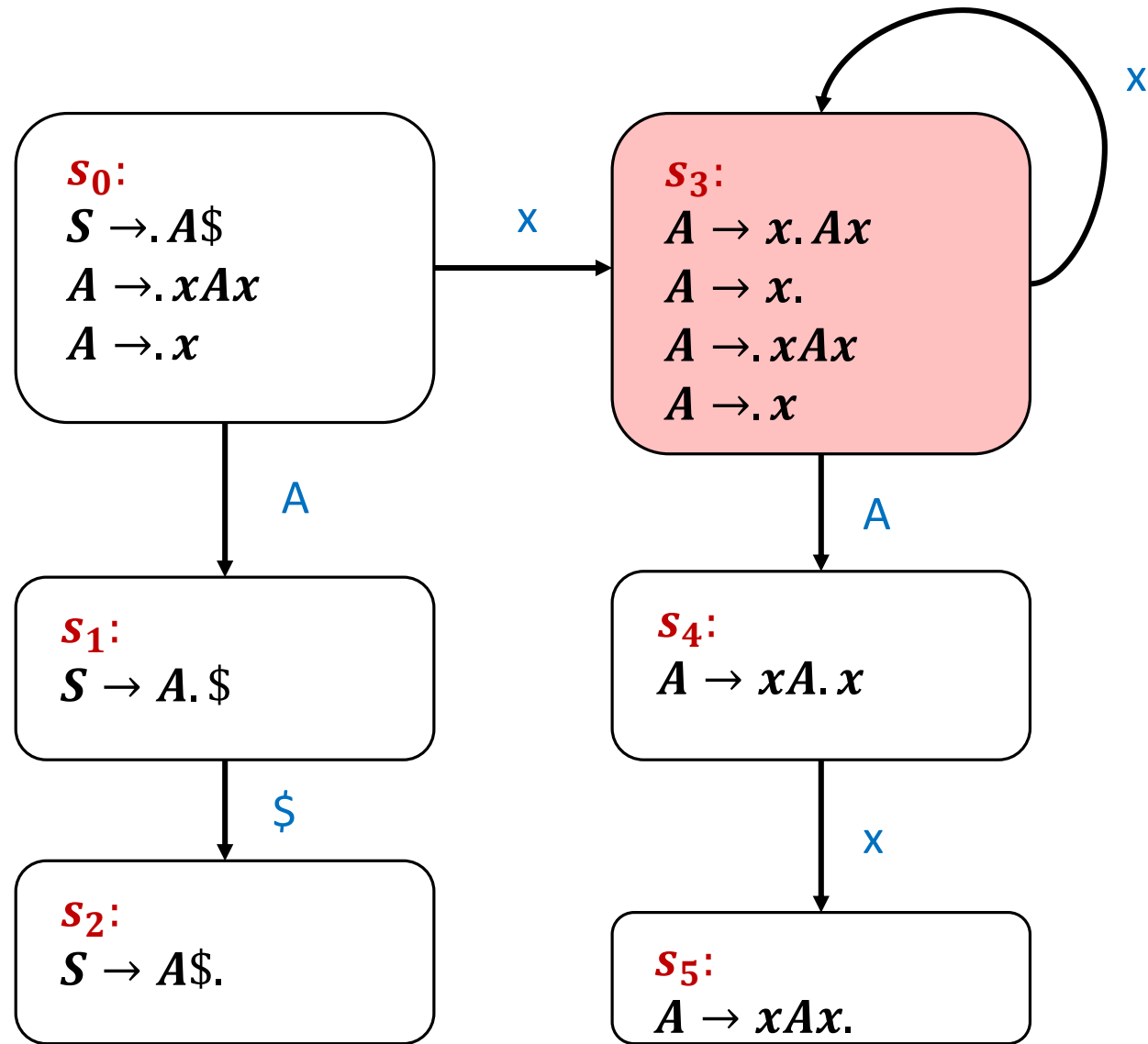
- $S \rightarrow A\$$
- $A \rightarrow xAx$
- $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$$\text{Follow}(A) = \{\$, x\}$$

$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$

s_0 :

$S \rightarrow .A\$ \{\$ \}$

$A \rightarrow .xAx \{\$ \}$

$A \rightarrow .x \{\$ \}$

$S \rightarrow A\$$

$A \rightarrow xAx$

$A \rightarrow x$

s_0 :

$S \rightarrow \cdot A \$ \{ \$ \}$

$A \rightarrow \cdot x A x \{ \$ \}$

$A \rightarrow \cdot x \{ \$ \}$

A

s_1 :

$S \rightarrow A \cdot \$ \{ \$ \}$

$S \rightarrow A \$$

$A \rightarrow x A x$

$A \rightarrow x$

s_0 :
 $S \rightarrow \cdot A \$ \{ \$ \}$
 $A \rightarrow \cdot x A x \{ \$ \}$
 $A \rightarrow \cdot x \{ \$ \}$



A

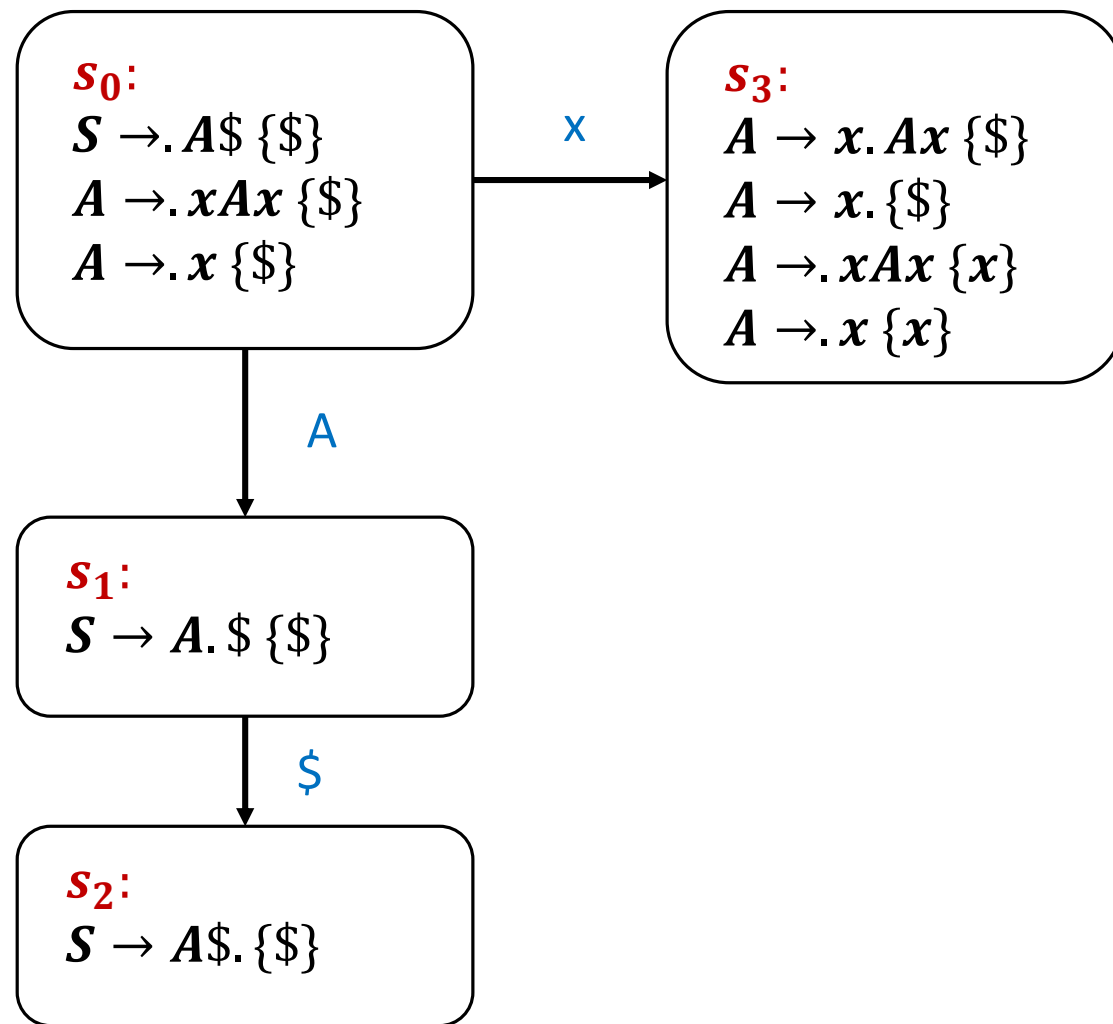
s_1 :
 $S \rightarrow A \cdot \$ \{ \$ \}$



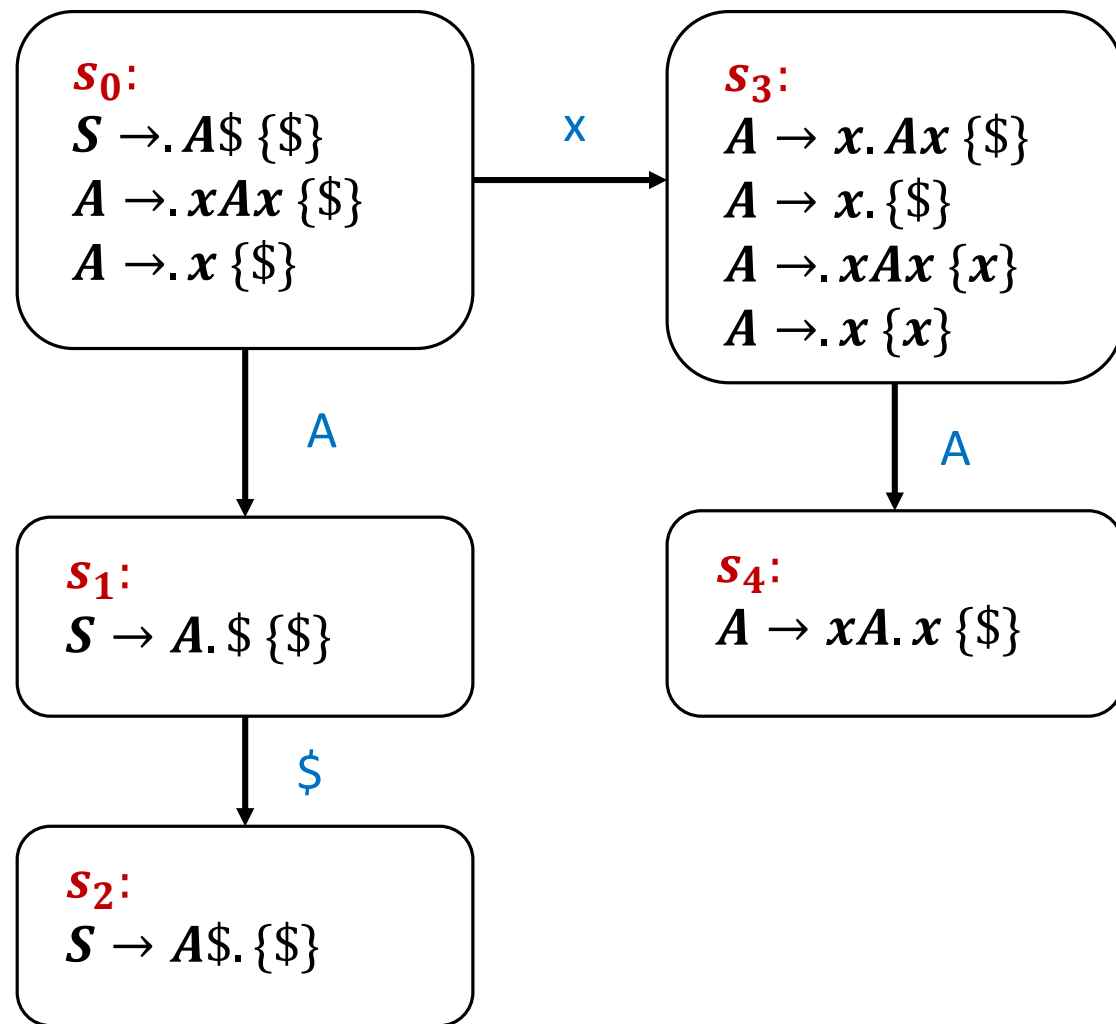
$\$$

s_2 :
 $S \rightarrow A \$ \cdot \{ \$ \}$

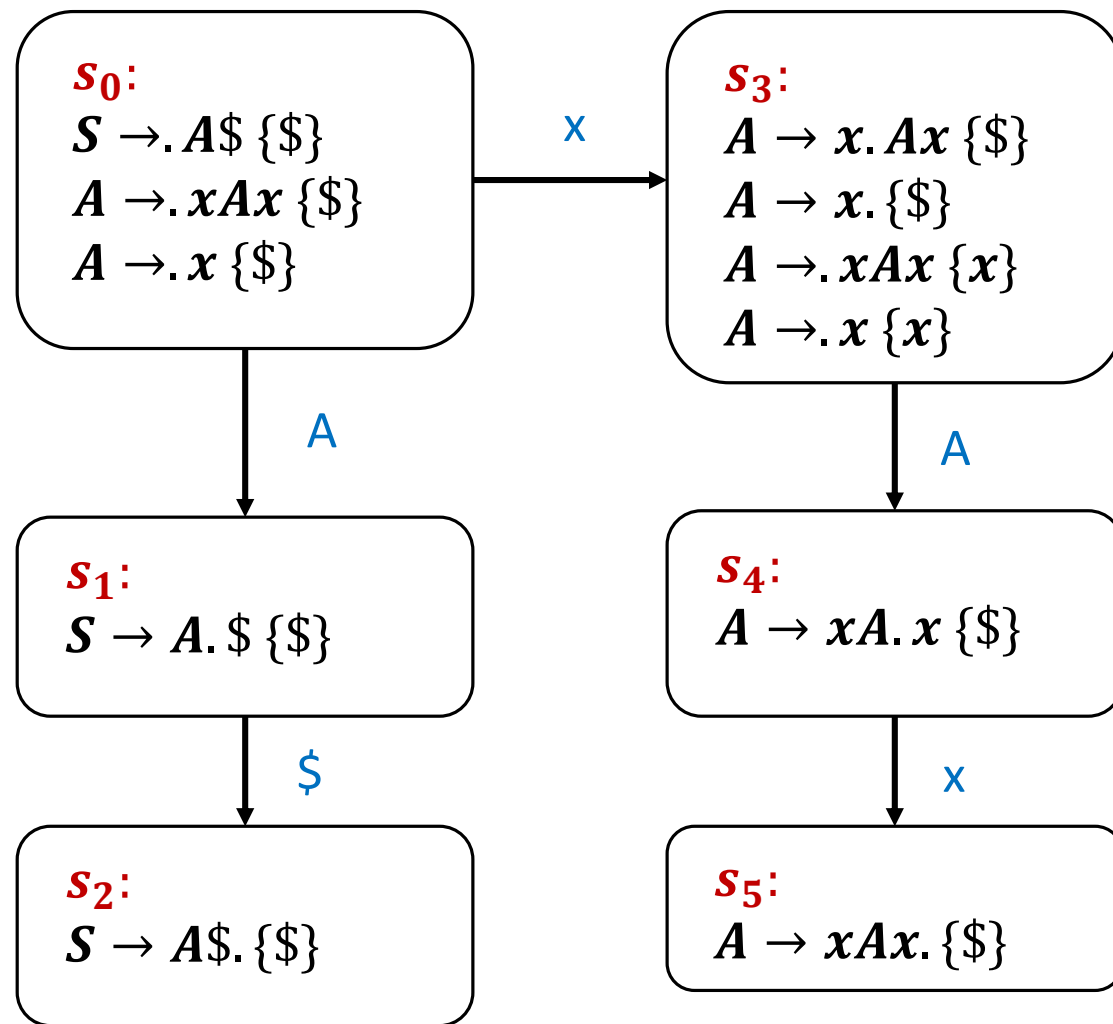
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



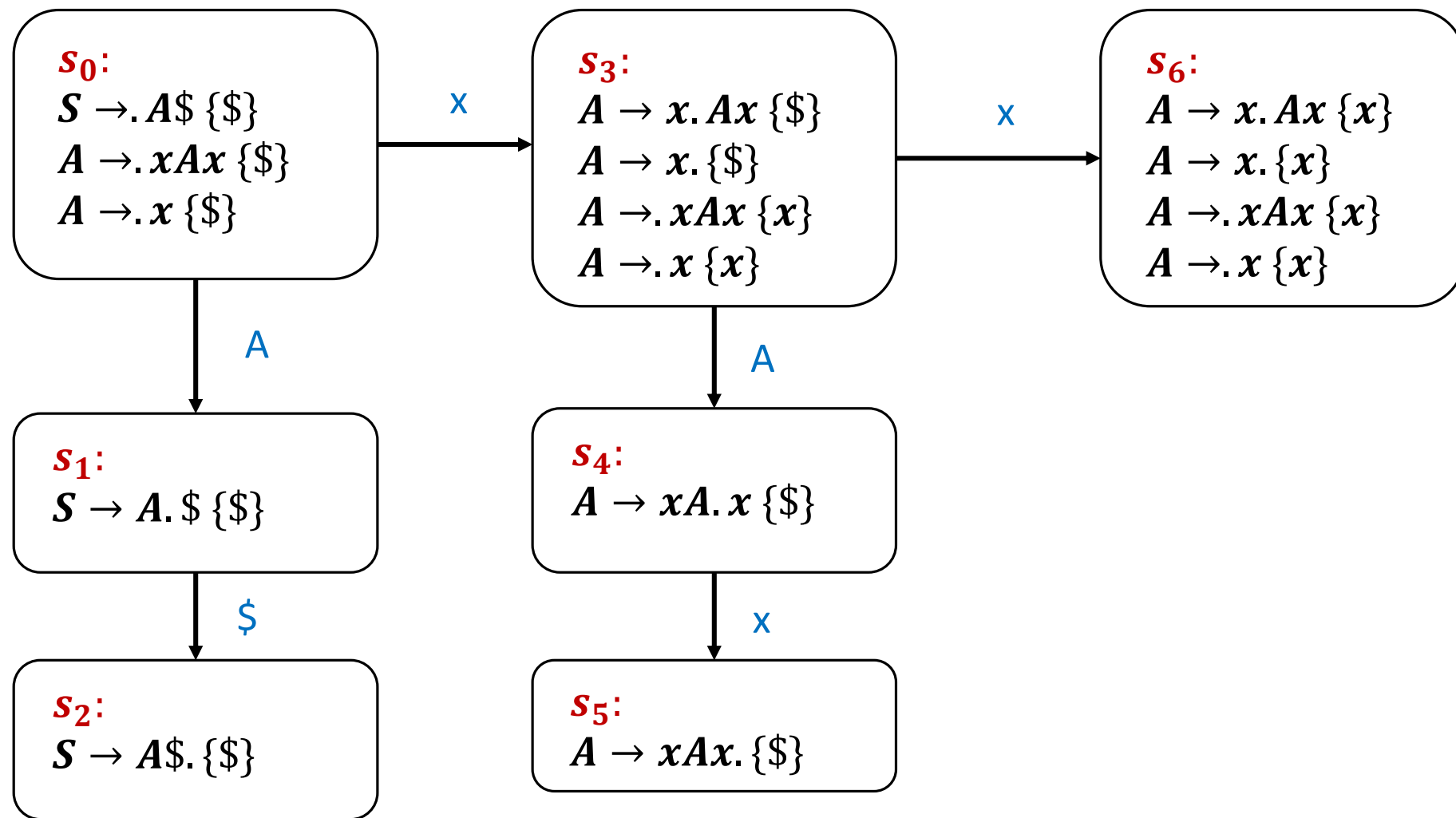
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



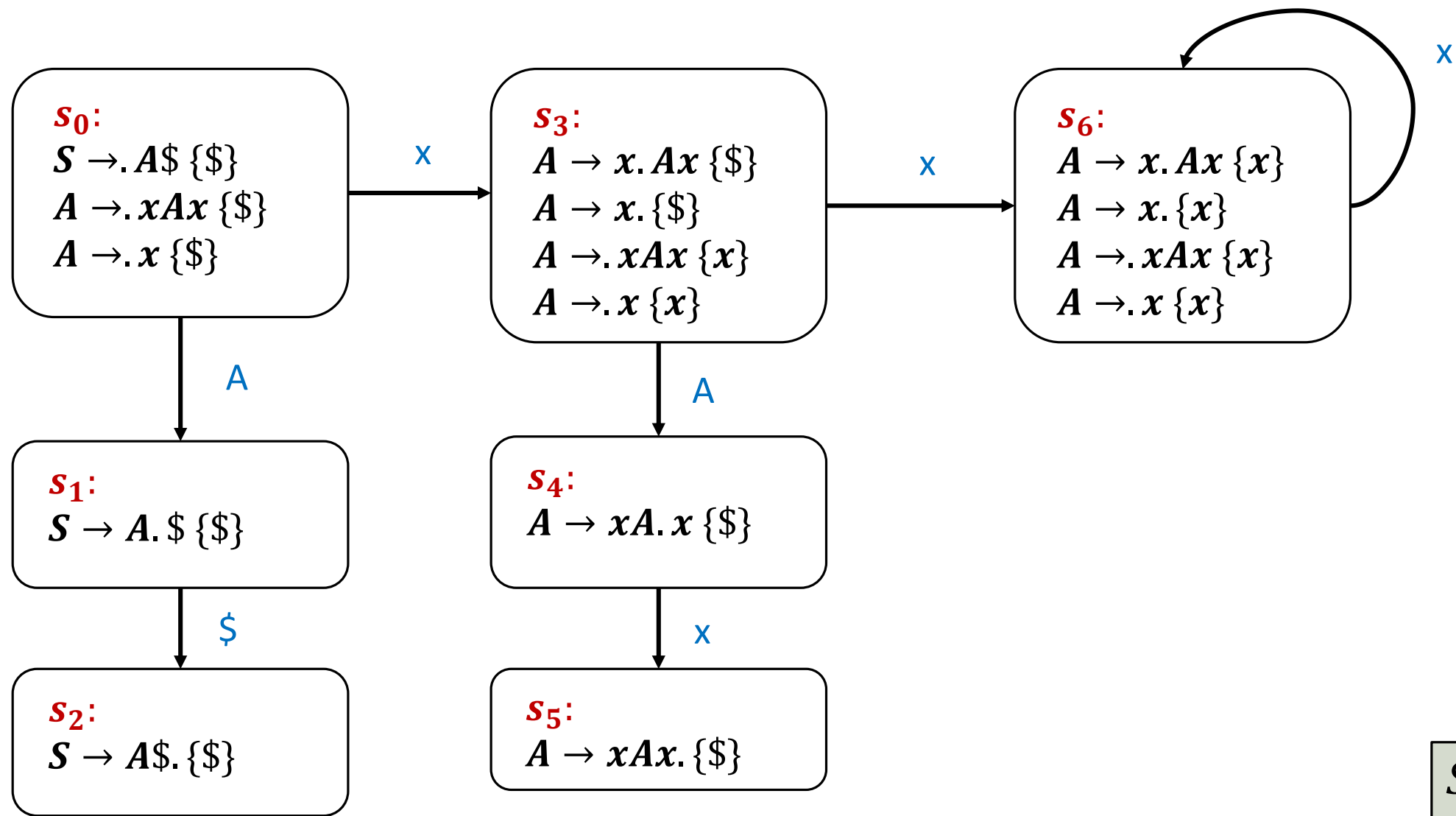
$S \rightarrow A \$$
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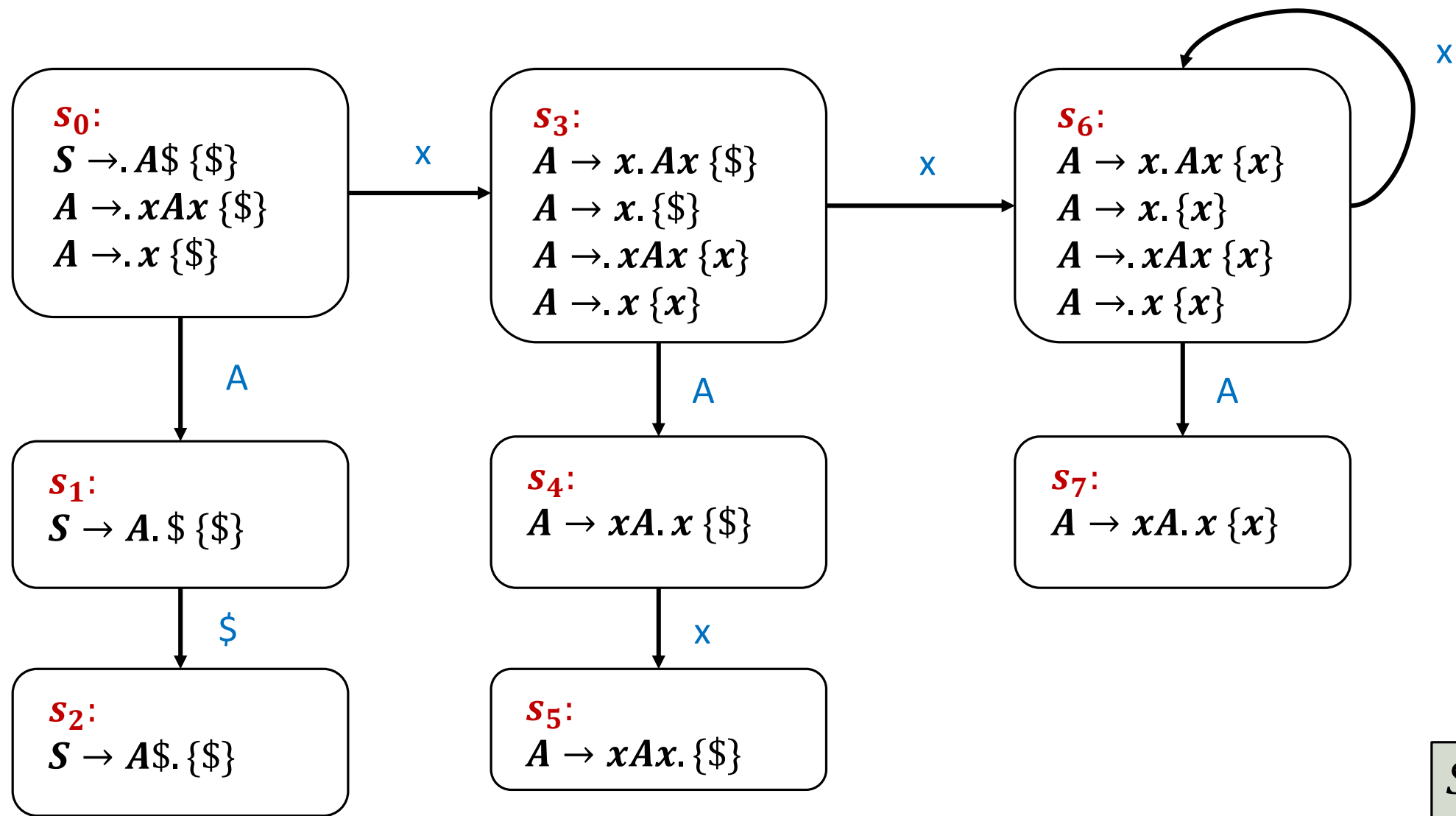
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



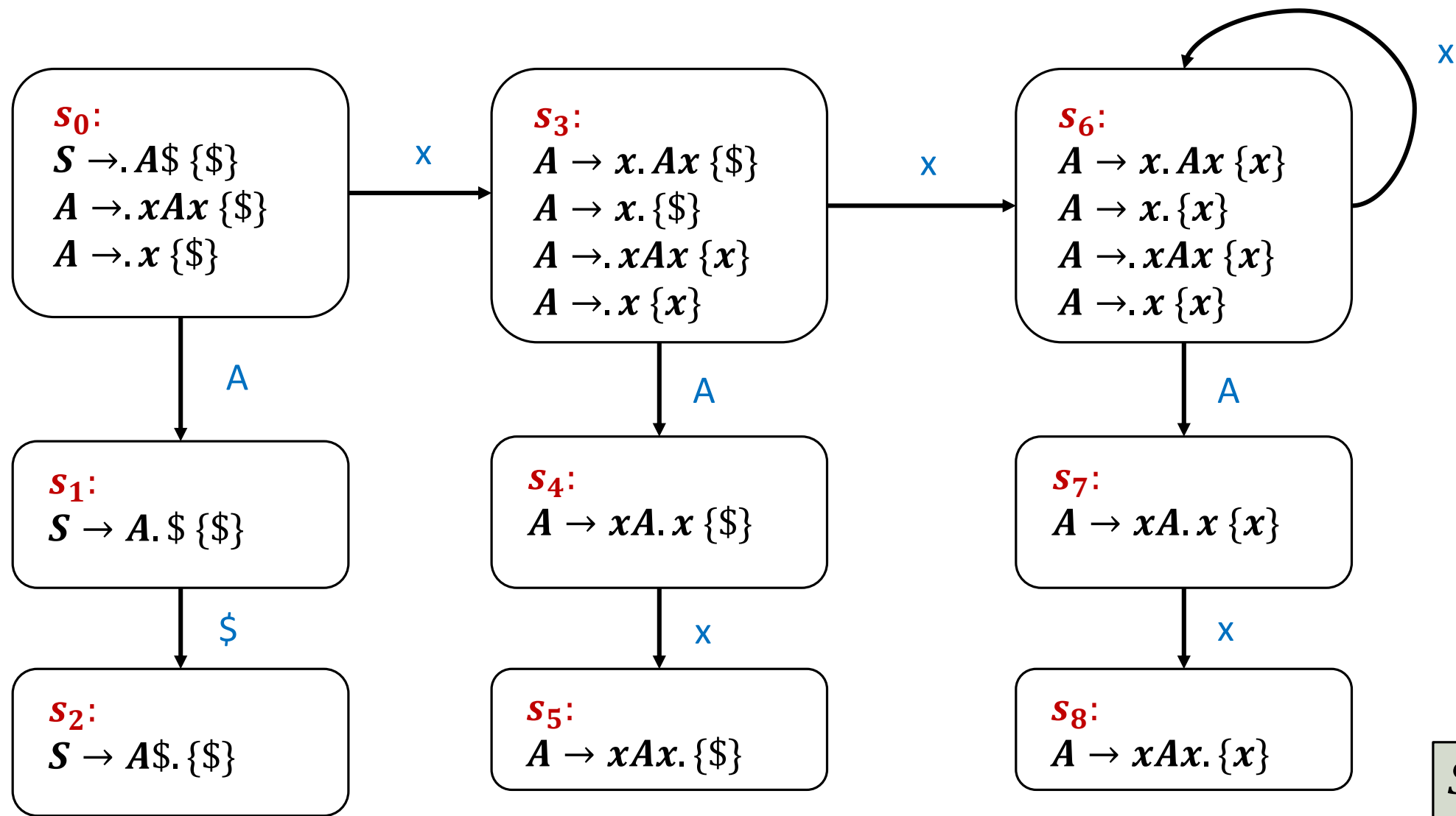
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



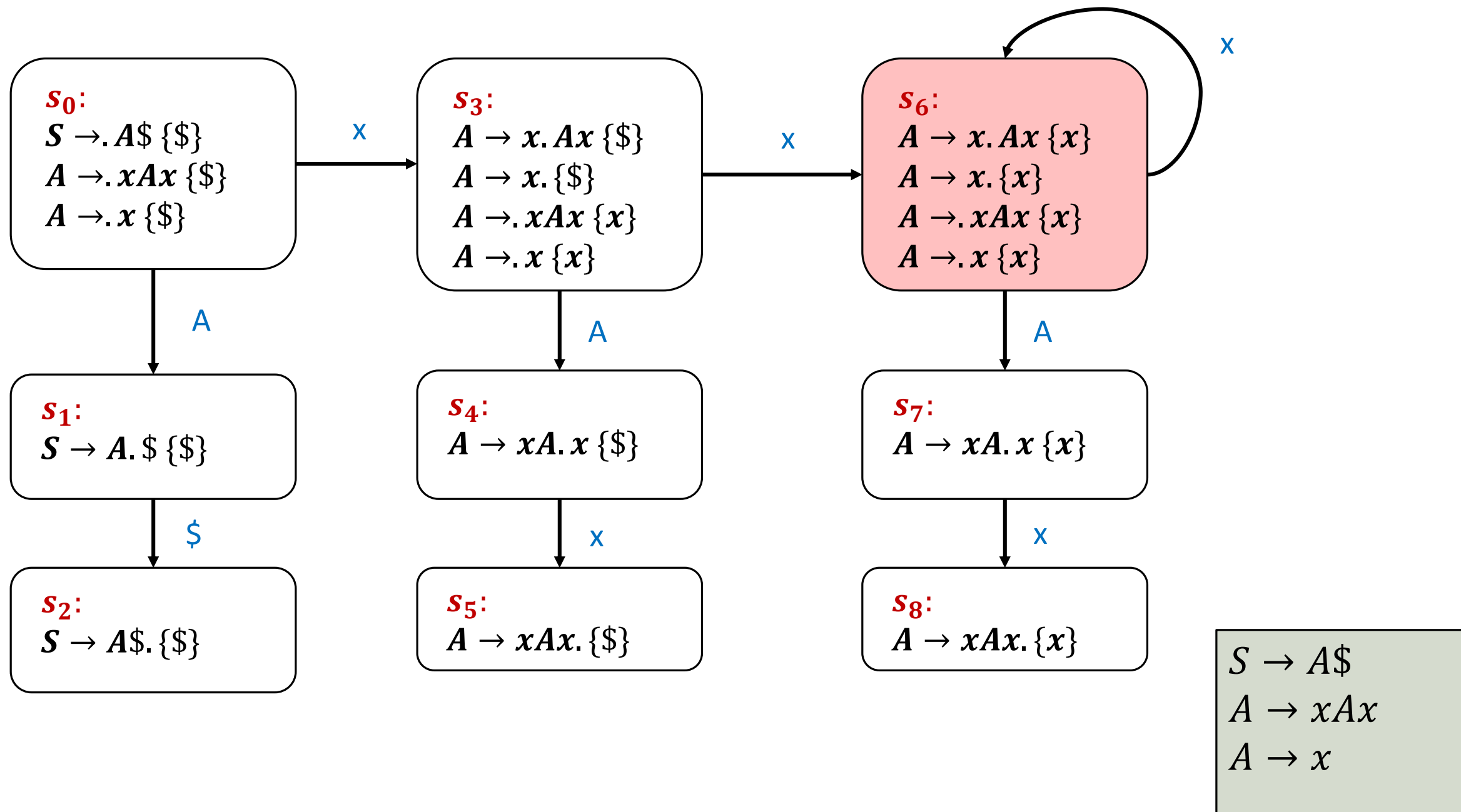
$S \rightarrow A \$$
 $A \rightarrow x A x$
 $A \rightarrow x$



$S \rightarrow A\$$
 $A \rightarrow xAx$
 $A \rightarrow x$



$S \rightarrow A\$$
 $A \rightarrow xAx$
 $A \rightarrow x$



Question

We extend the language with automatic type inference:

- Can use **auto** when the declaration has an initial value

Describe the changes required in:

- Lexical analysis
- Syntactic analysis
- Semantic analysis

```
auto i := 8 + 100;  
auto s := "1234";  
class A {}  
A a := new A;  
auto b := a;
```

Question

A variable x **depends** on a variable y if y is used (directly or indirectly) to compute x . For example, c depends on x, y, b, z but not on t .

- Define a static analysis in terms of (D, V, \sqcup, F, I)
- Run on the example

```
y := t;  
y := z + 5;  
if (x > 0) {  
    x := y * 2;  
} else {  
    x := y + b;  
}  
c := x;
```


Abstract Domain

We define (D, V, \sqcup, F, I) :

Abstract Domain

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- Forward analysis

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- V contains maps of the form:
 - $Var \mapsto P(Var)$ (e.g., $\{a : \{b, c\}\}$)

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- V contains maps of the form:
 - $Var \mapsto P(Var)$ (e.g., $\{a : \{b, c\}\}$)
- Join operator:
 - $m_1 \sqcup m_2 := \lambda v. m_1[v] \cup m_2[v]$
 - $\{a : \{b\}\} \sqcup \{a : \{c\}, d : \{e\}\} = \{a : \{b, c\}, d : \{e\}\}$

Abstract Domain

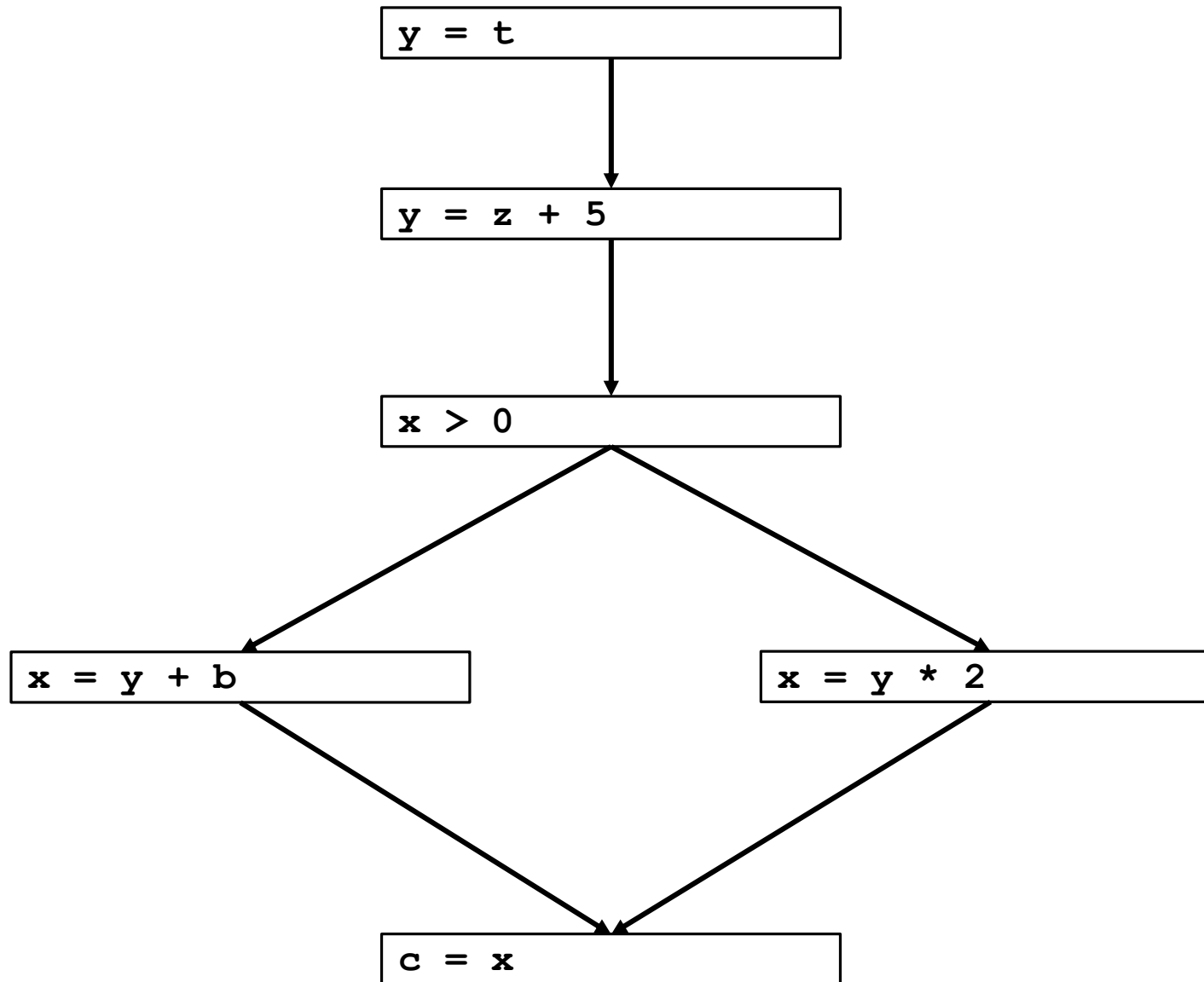
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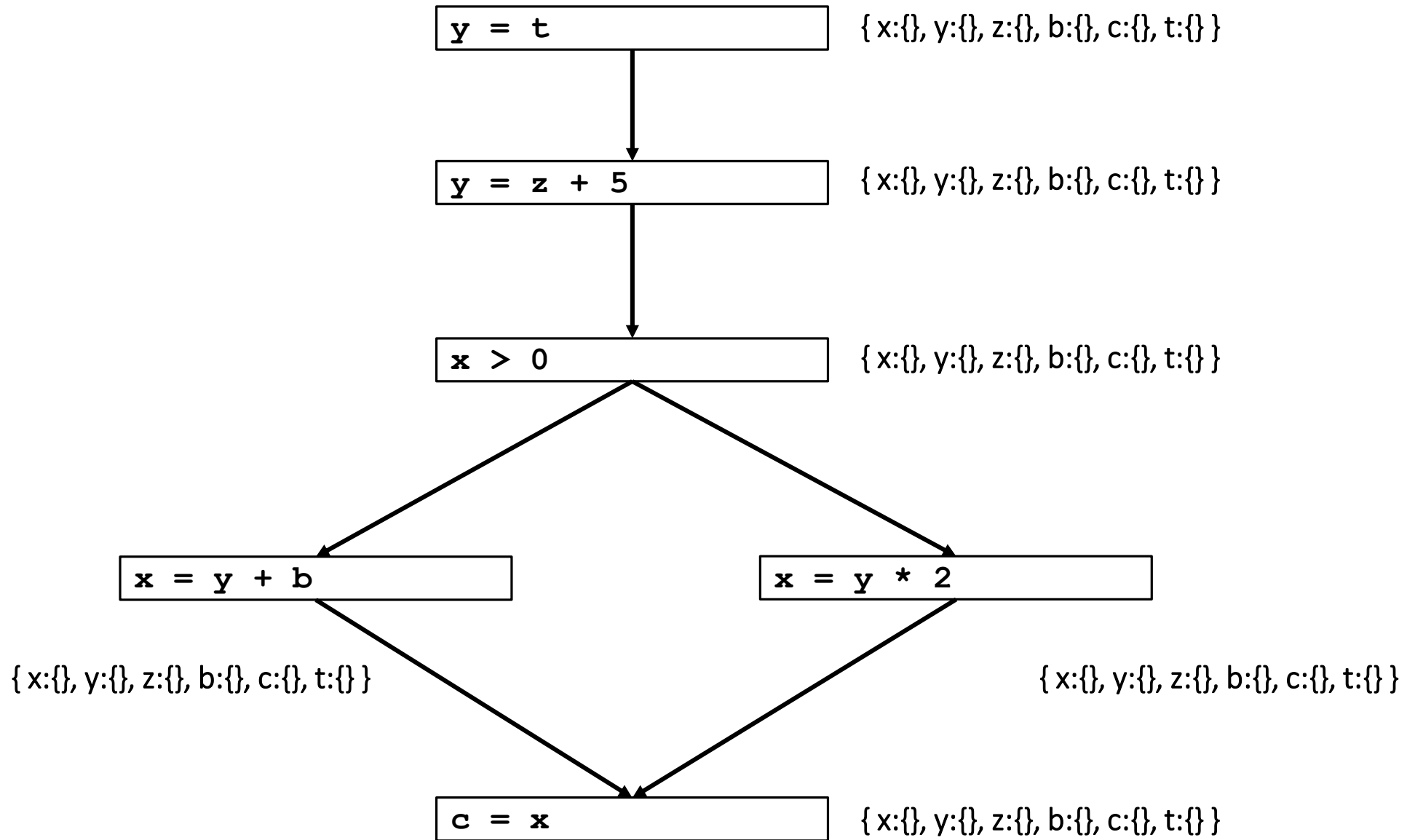
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 - $\{a : \{b\}\} \sqcup \{a : \{c\}, d : \{e\}\} = \{a : \{b, c\}, d : \{e\}\}$
- For example, for $a = b + c$:
 - $\{a : s_a, b : s_b, c : s_c, \dots\} \rightarrow \{a : \{b, c\} \cup s_b \cup s_c, b : s_b, c : s_c, \dots\}$

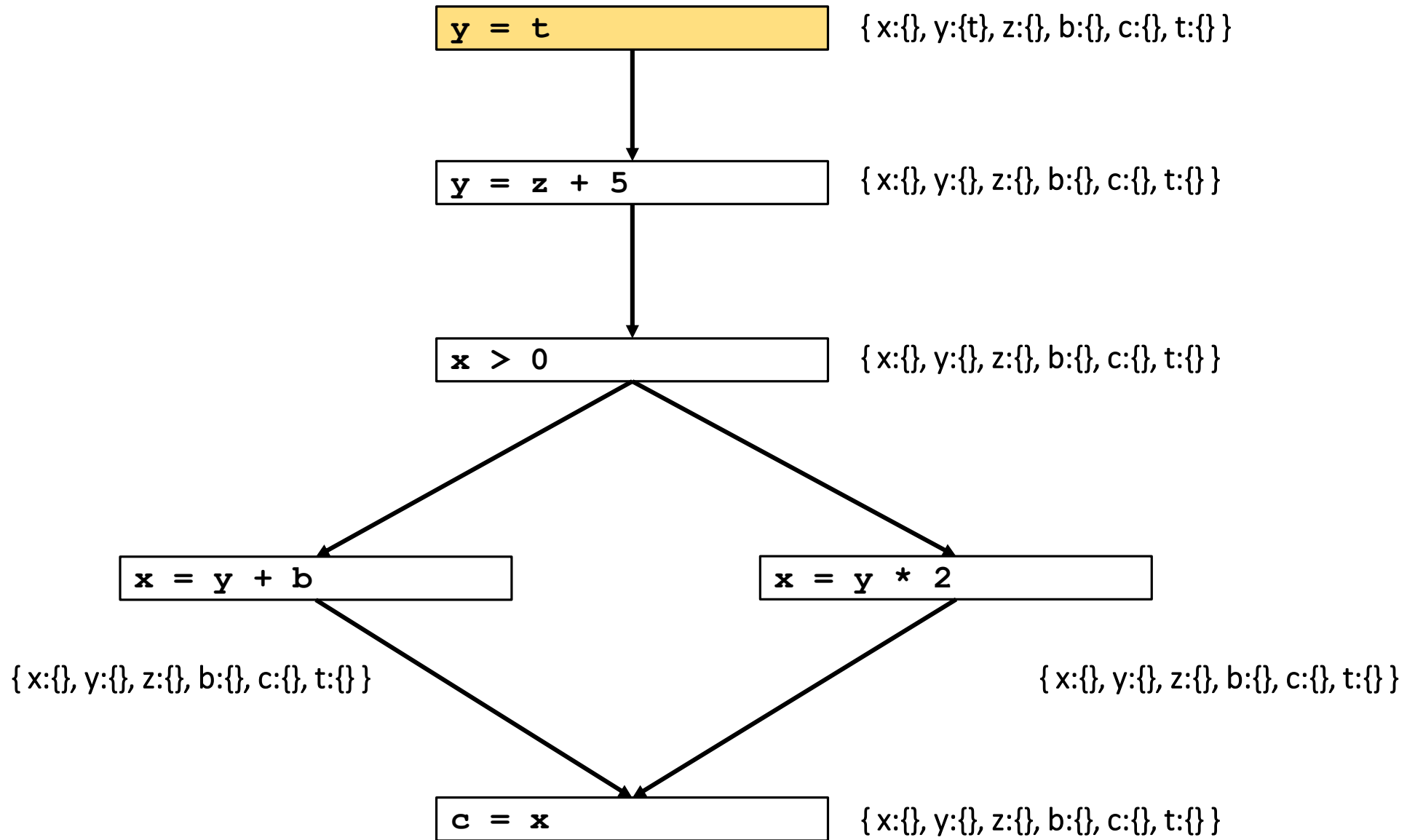
Abstract Domain

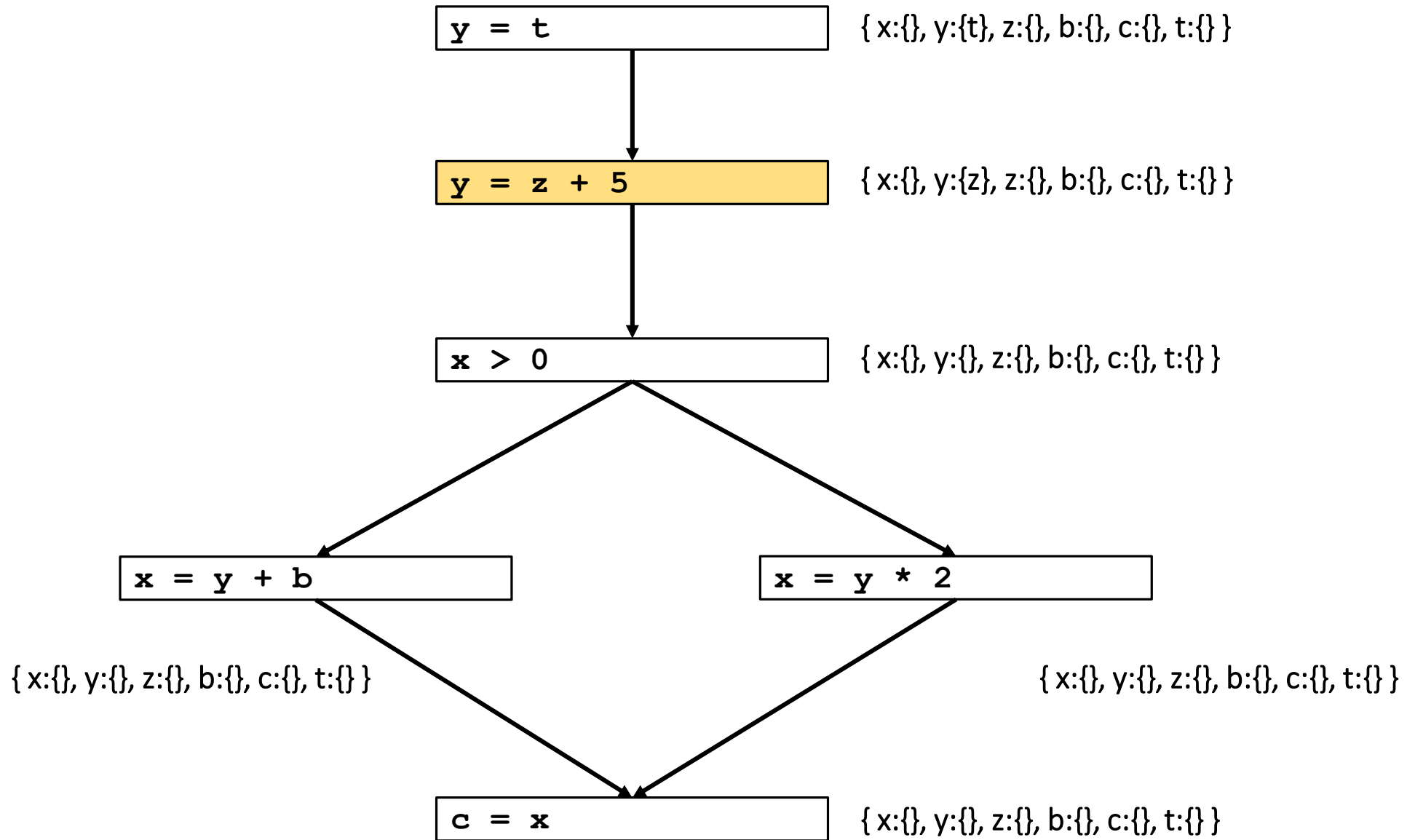
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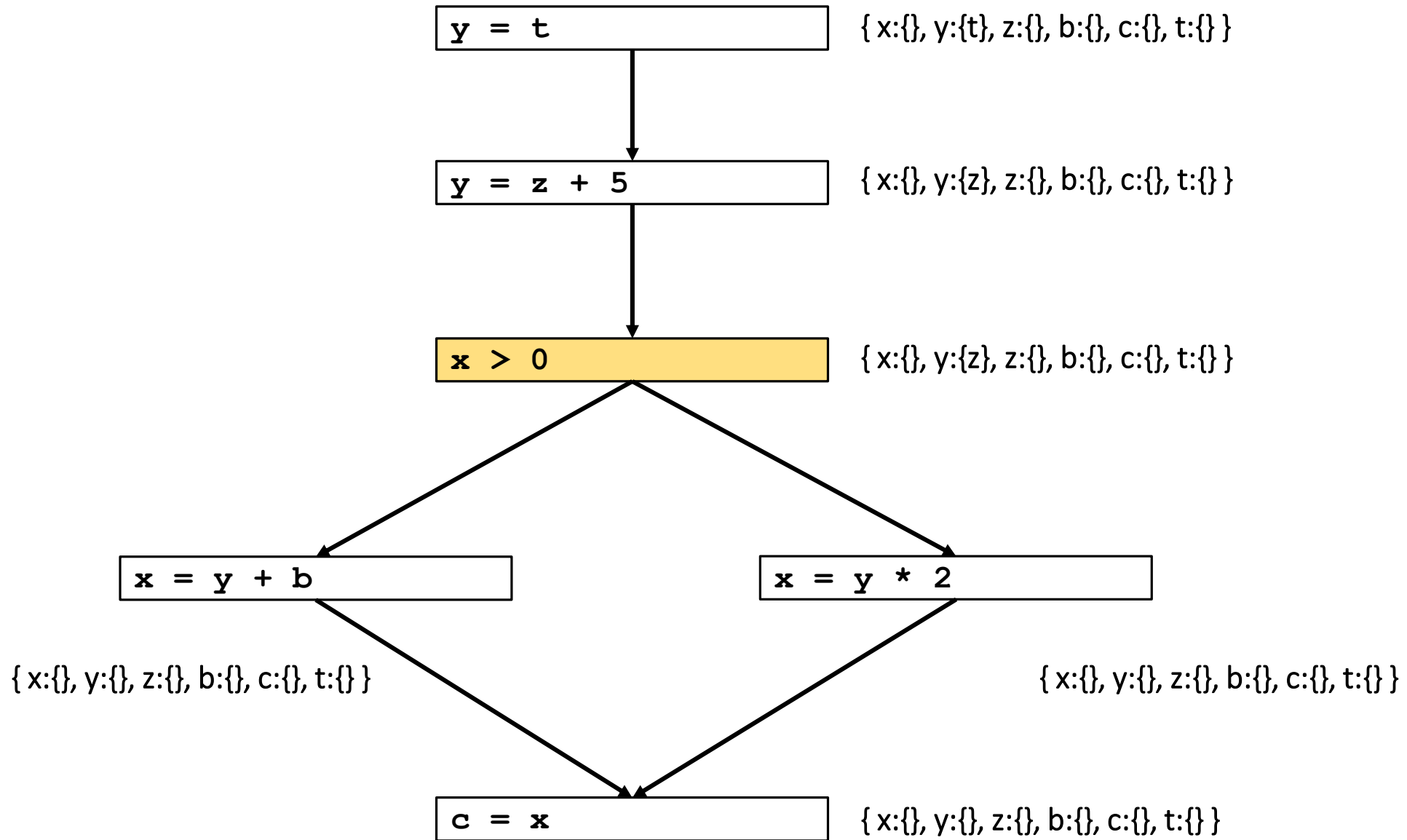
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- Initialize with:
 - $\lambda v. \{\}$

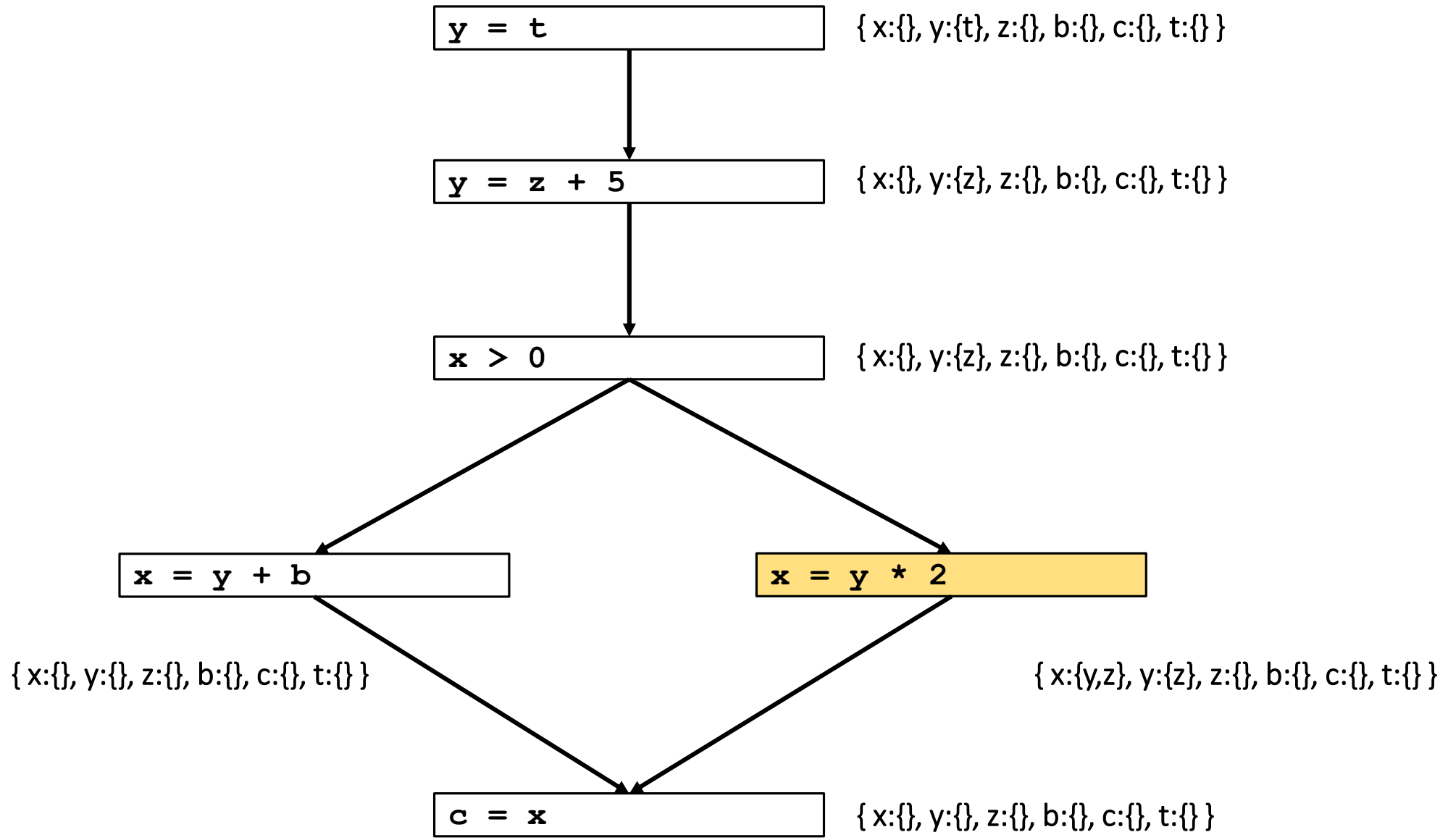


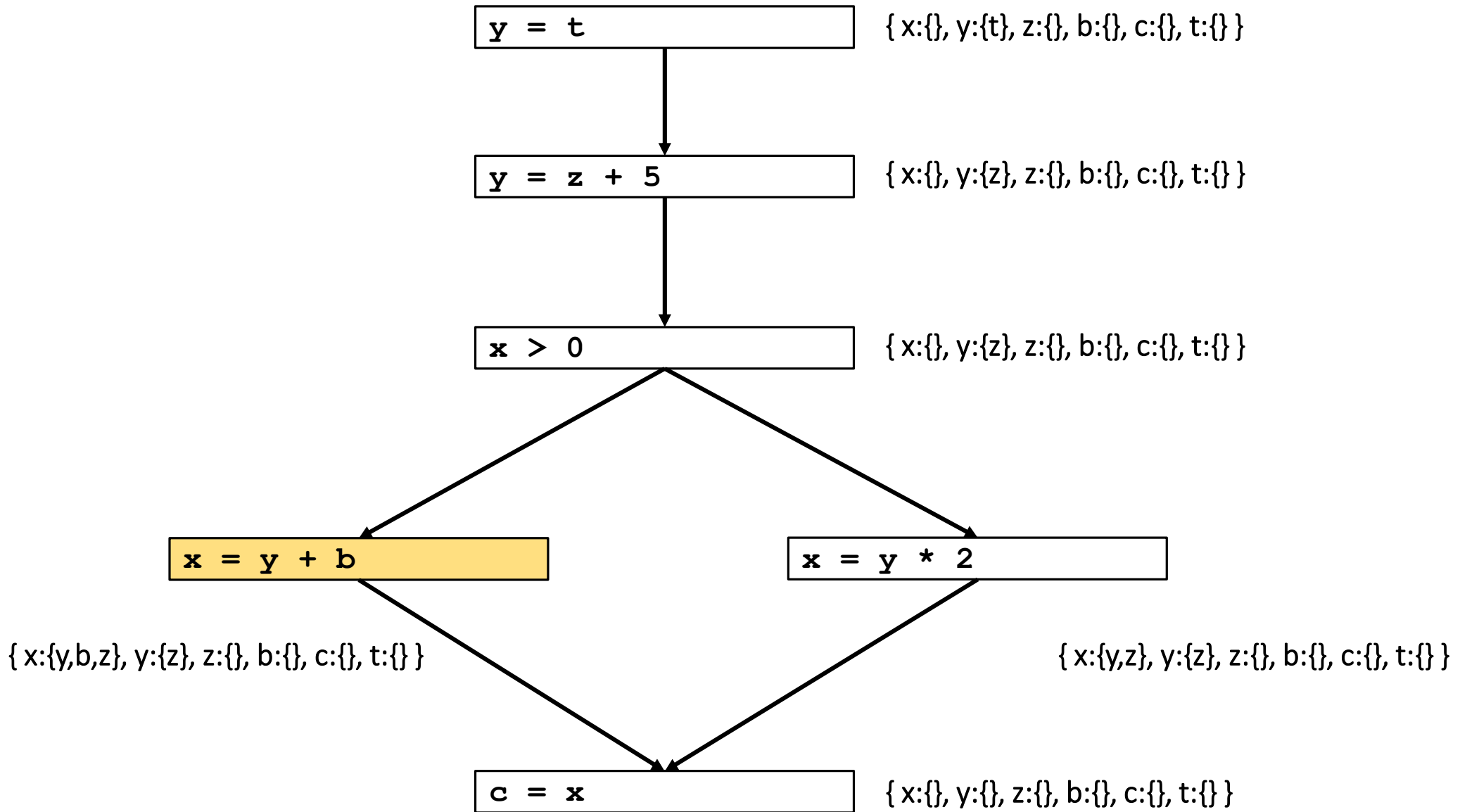


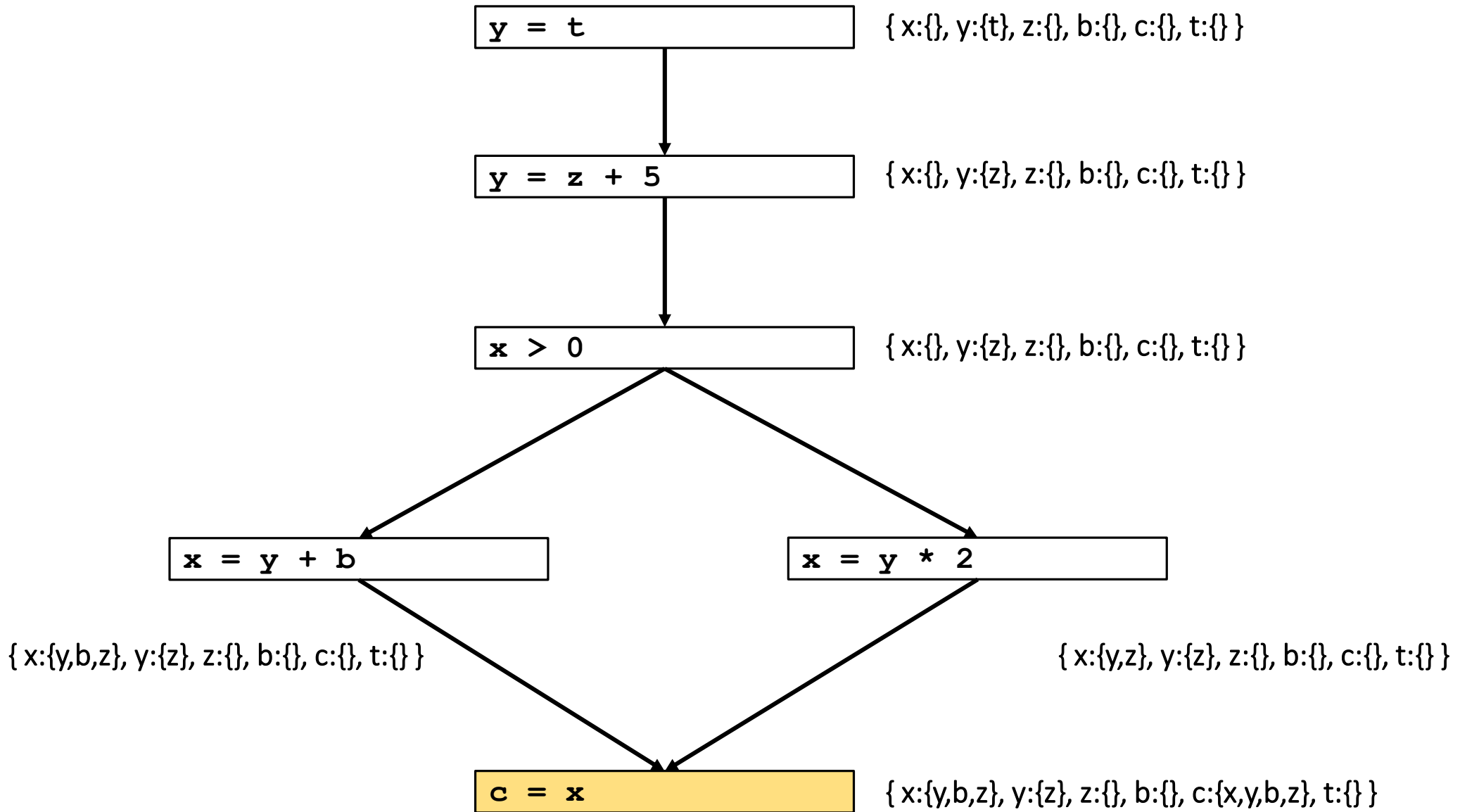












Question

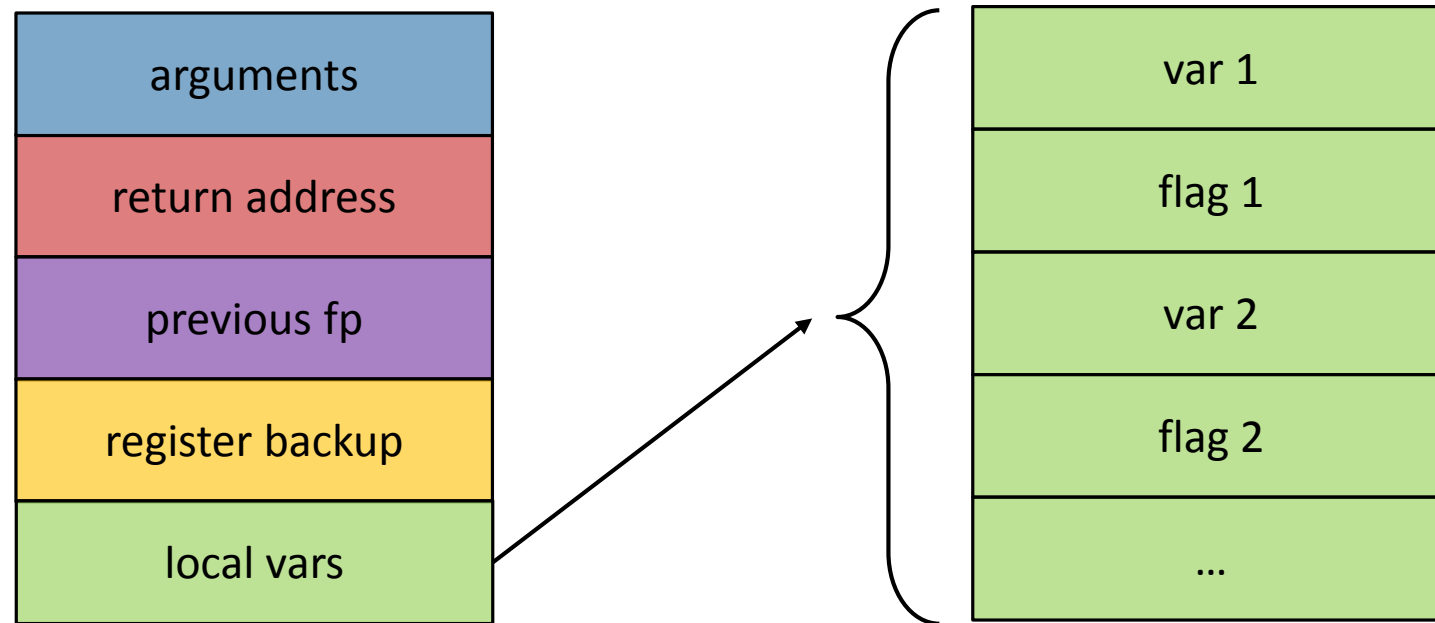
Add support for detecting accesses to uninitialized local variables.
Describe the required changes in the code generation step.

For example:

```
void f() {  
    int x;  
    int y := 7;  
    if (y > 10) {  
        x := 100;  
    }  
    int z := x + 1;  
}
```

Solution

High level idea:



Solution

- Initialize each variable flag to zero on function entry
- When writing to a local variable, set its flag to 1
- When reading a local variable, check if its flag is 1

var 1
flag 1
var 2
flag 2
...

Solution

- Initialize each variable flag to zero on function entry
- When writing to a local variable, set its flag to 1
- When reading a local variable, check if its flag is 1

prologue:

```
...  
li $s0, 0  
sw $s0, local_1_flag_offset($fp)  
li $s0, 0  
sw $s0, local_2_flag_offset($fp)  
...
```

var 1
flag 1
var 2
flag 2
...

Solution

- Initialize each variable flag to zero on function entry
- **When writing to a local variable, set its flag to 1**
- When reading a local variable, check if its flag is 1

x = t0

```
sw $t0, x_offset($fp)
li $s0, 1
sw $s0, x_flag_offset($fp)
```

var 1
flag 1
var 2
flag 2
...

Solution

- Initialize each variable flag to zero on function entry
- When writing to a local variable, set its flag to 1
- **When reading a local variable, check if its flag is 1**

`t0 = x`

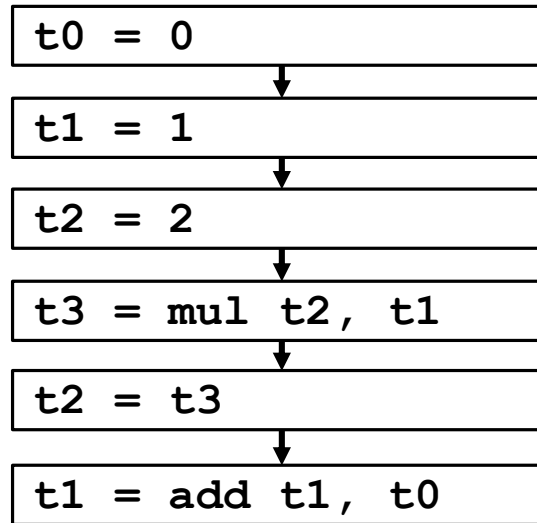
```
lw $s0, x_flag_offset($fp)
beq $s0, 0, abort
lw $t0, x_offset($fp)
```

var 1
flag 1
var 2
flag 2
...

Question

Apply the register allocation algorithm with 3 registers (R1,R2,R3)
R1 can't hold a result of a multiplication operation.

```
t0 = 0
t1 = 1
t2 = 2
t3 = t2 * t1
t2 = t3
t1 = t1 + t0
```



IN

{ }

{ }

{ }

{ }

{ }

{ }

OUT

{ }

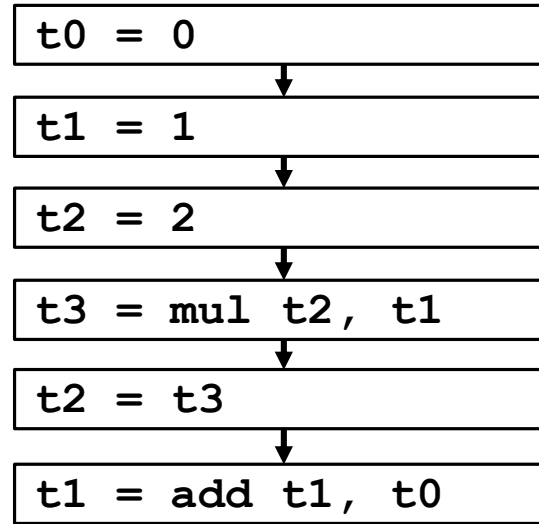
{ }

{ }

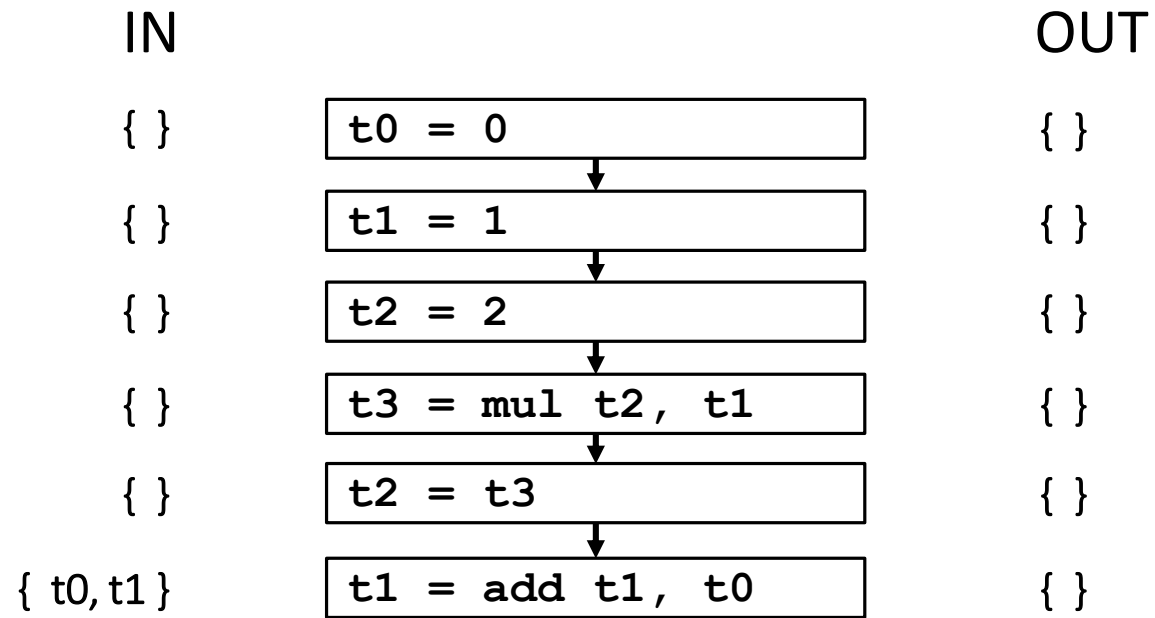
{ }

{ }

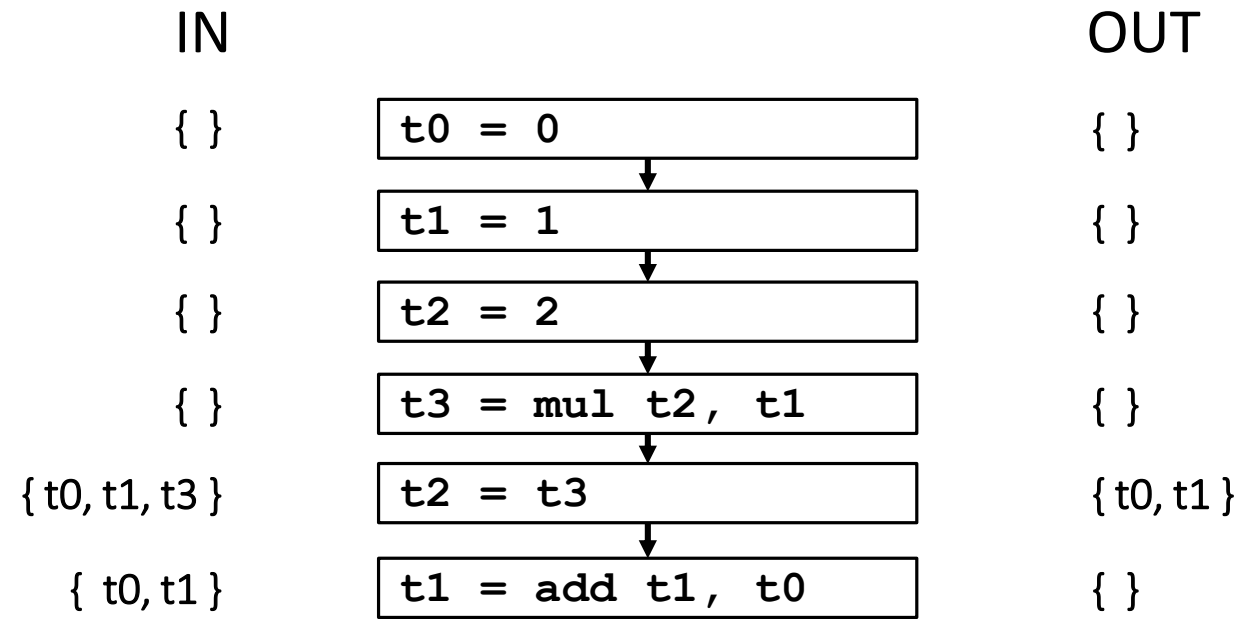
{ }



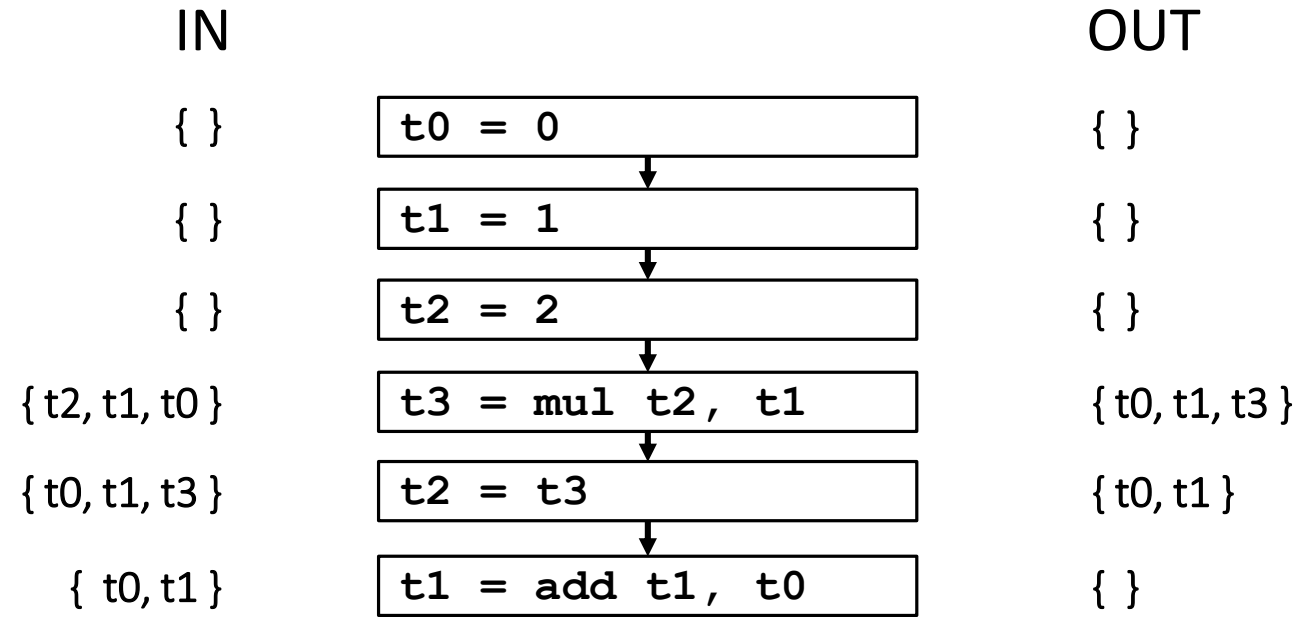
initialization



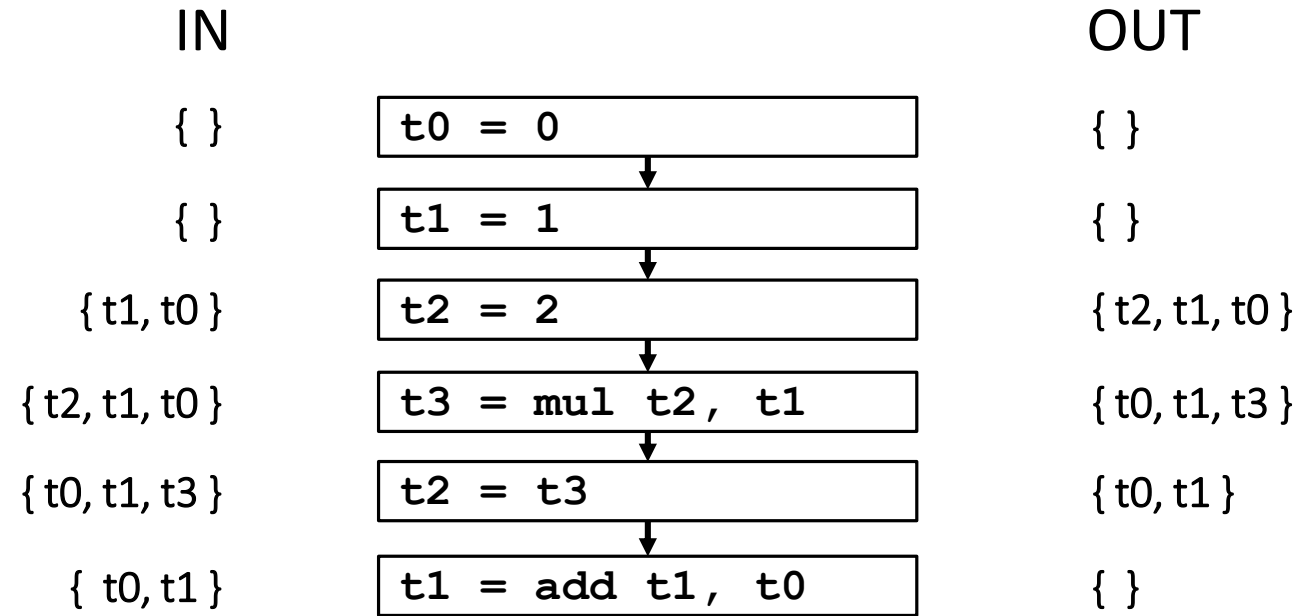
first iteration



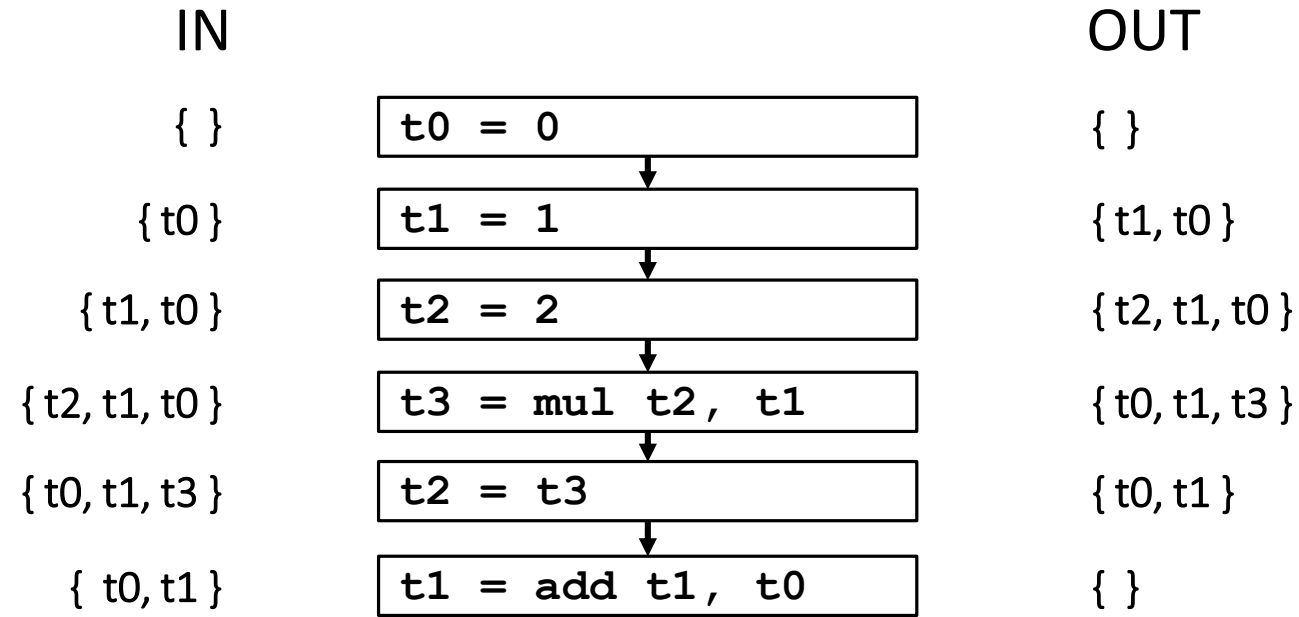
first iteration



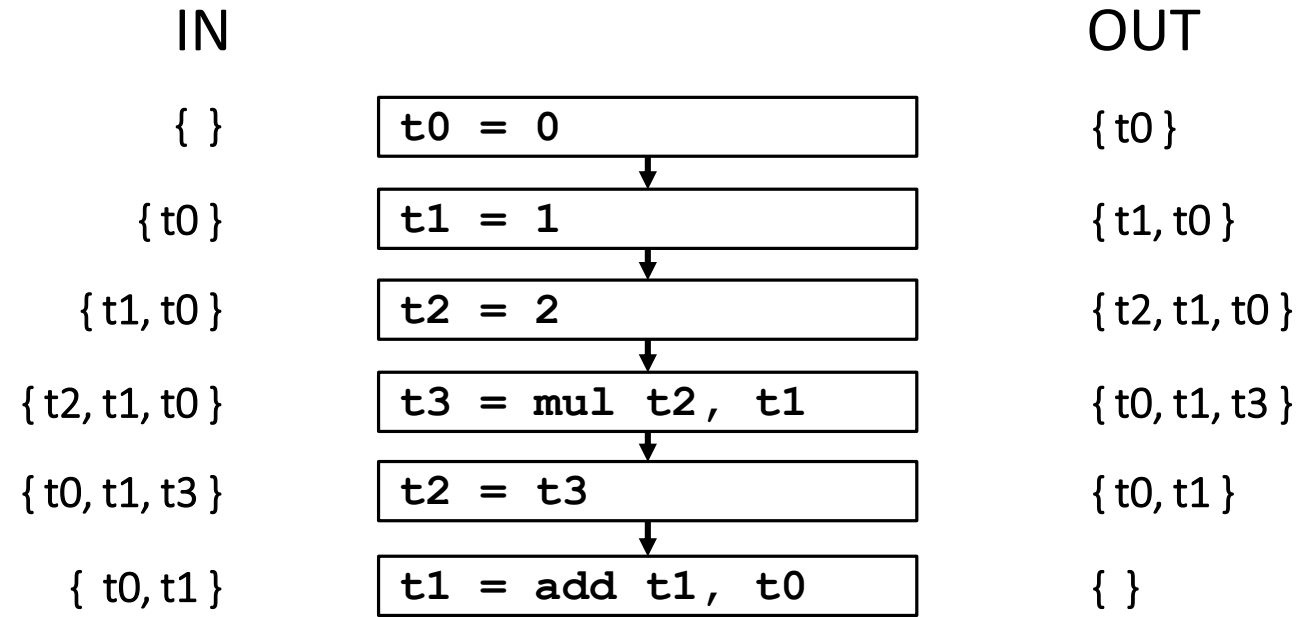
first iteration



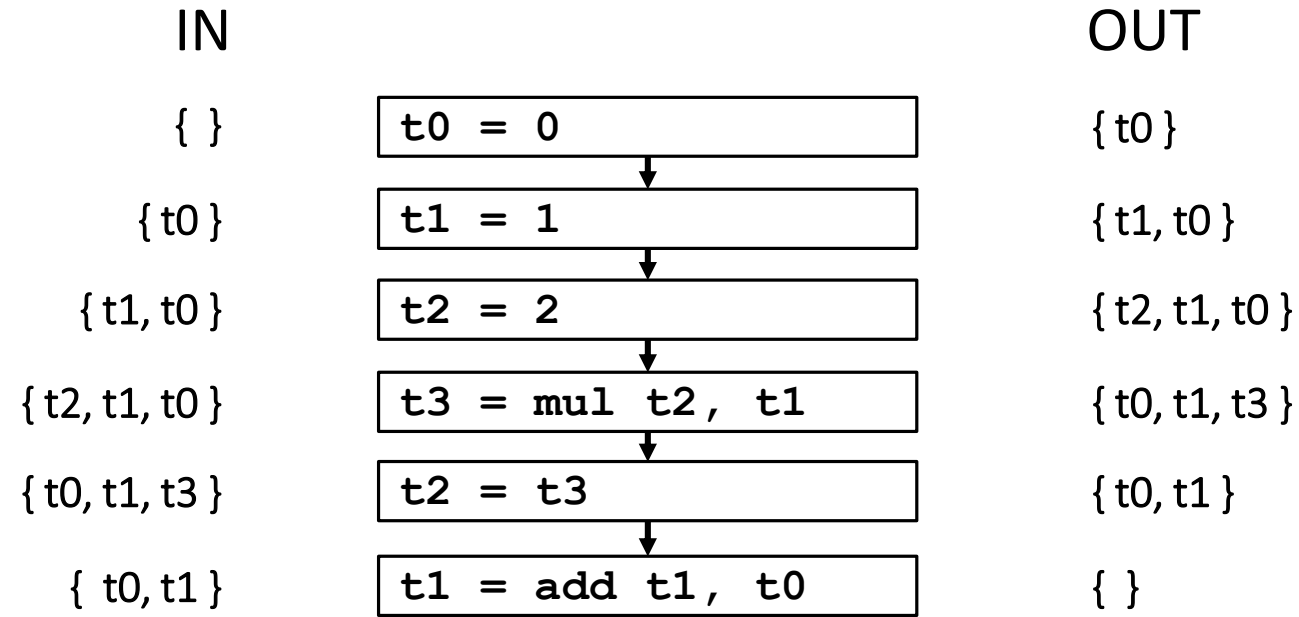
first iteration



first iteration



first iteration



second iteration...

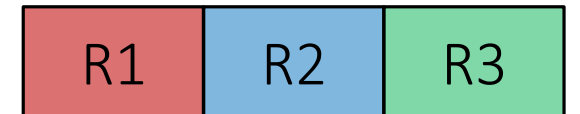
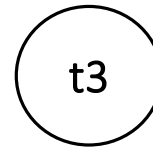
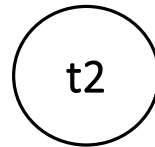
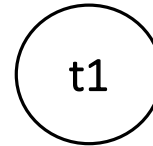
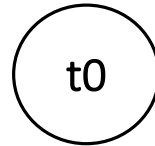
Interference Graph

$\{t_0\}$

$\{t_0, t_1\}$

$\{t_0, t_2, t_1\}$

$\{t_0, t_3\}$



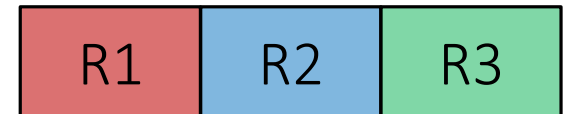
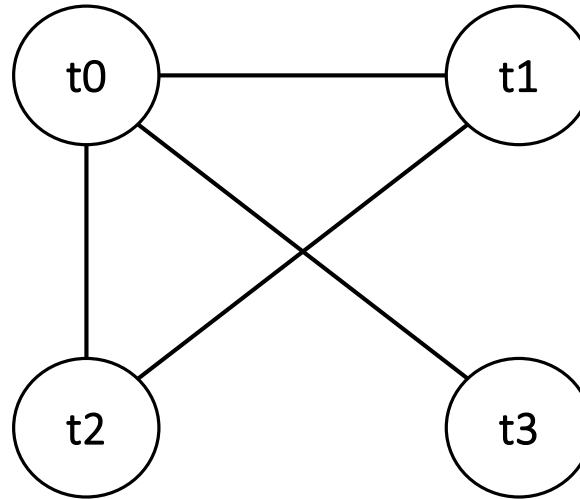
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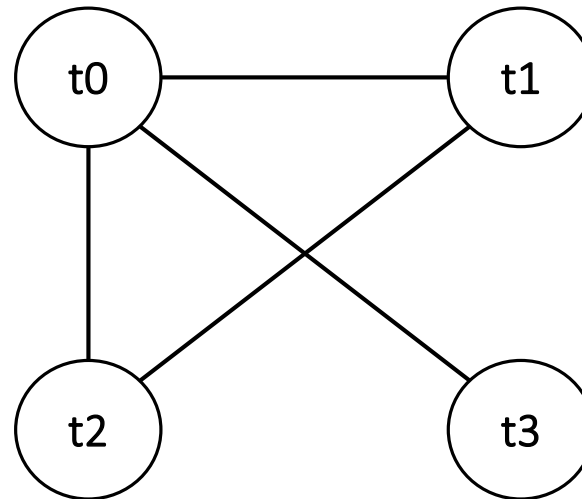
Interference Graph

{ t0 }

{ t0, t1 }

{ t0, t2, t1 }

{ t0, t3 }



t0 = 0

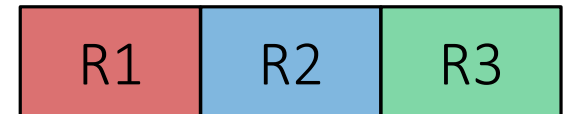
t1 = 1

t2 = 2

t3 = t2 * t1

t2 = t3

t1 = t1 + t0



Interference Graph

{ t0 }

{ t0, t1 }

{ t0, t2, t1 }

{ t0, t3 }

t0 = 0

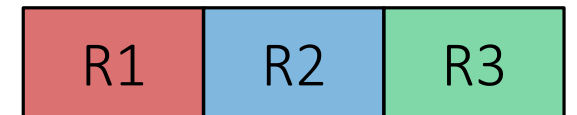
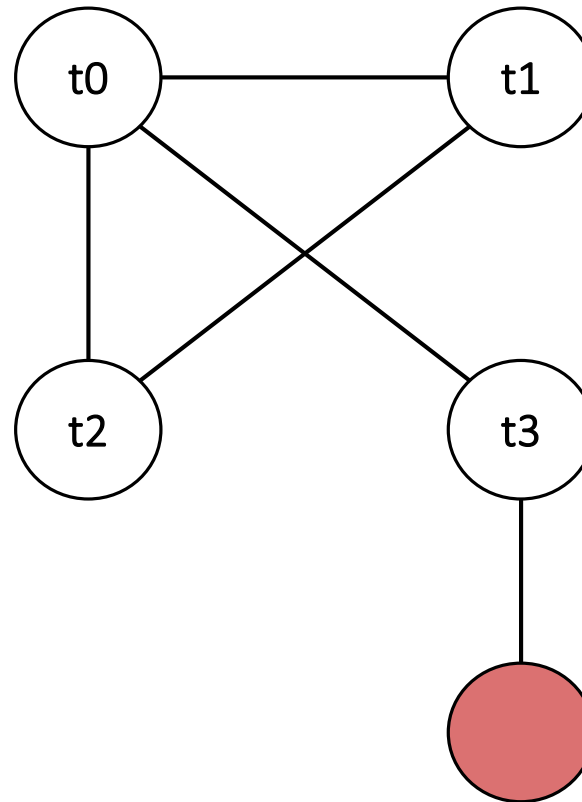
t1 = 1

t2 = 2

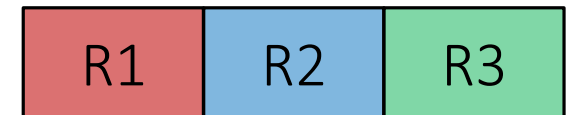
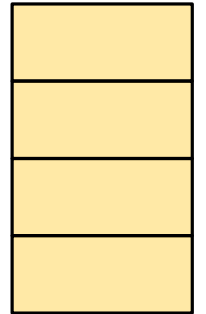
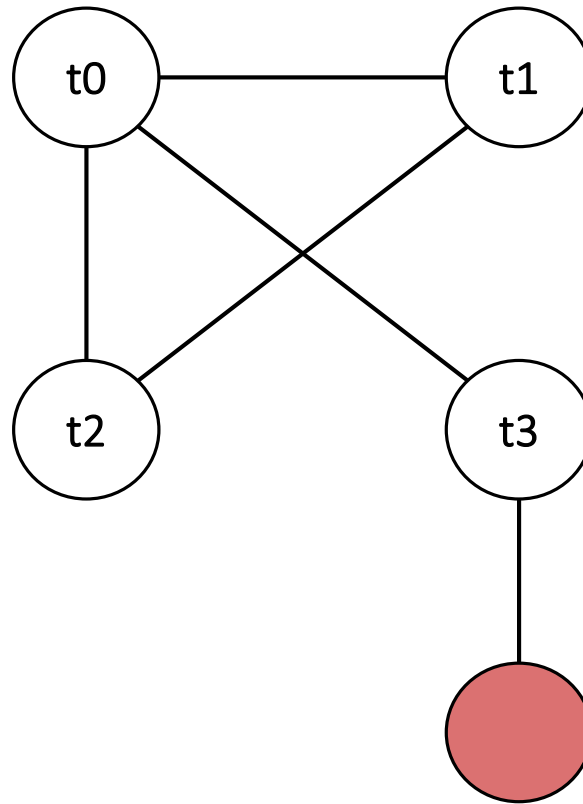
t3 = t2 * t1

t2 = t3

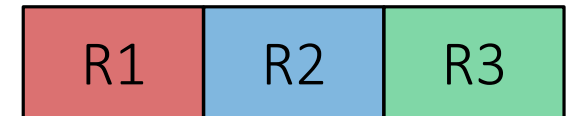
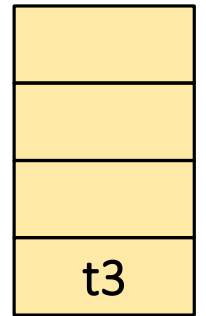
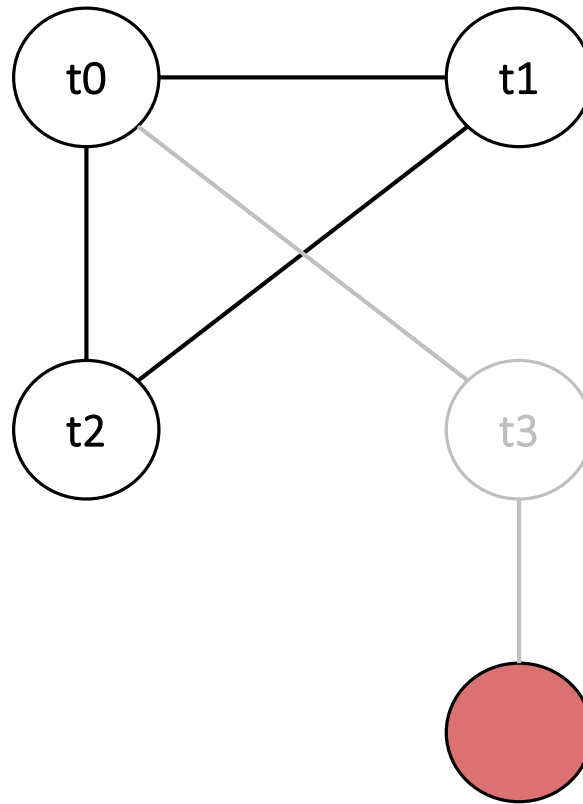
t1 = t1 + t0



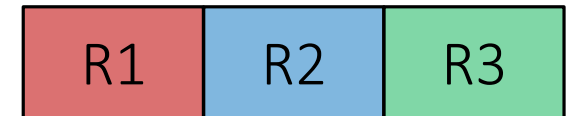
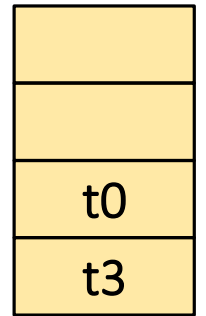
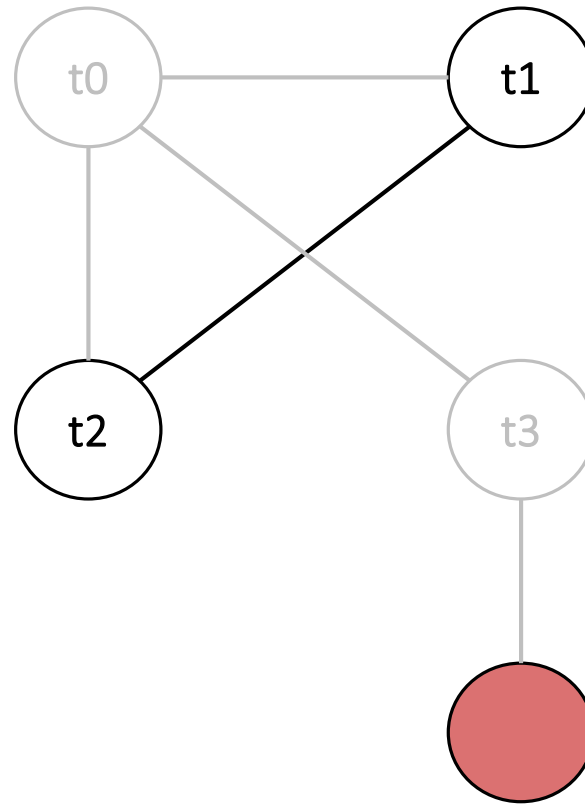
Graph Coloring



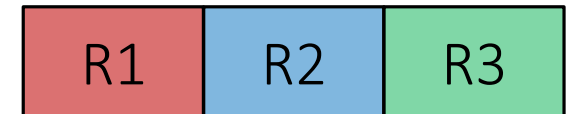
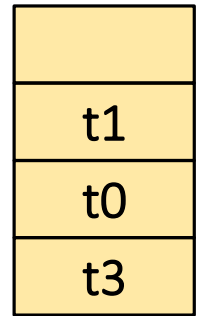
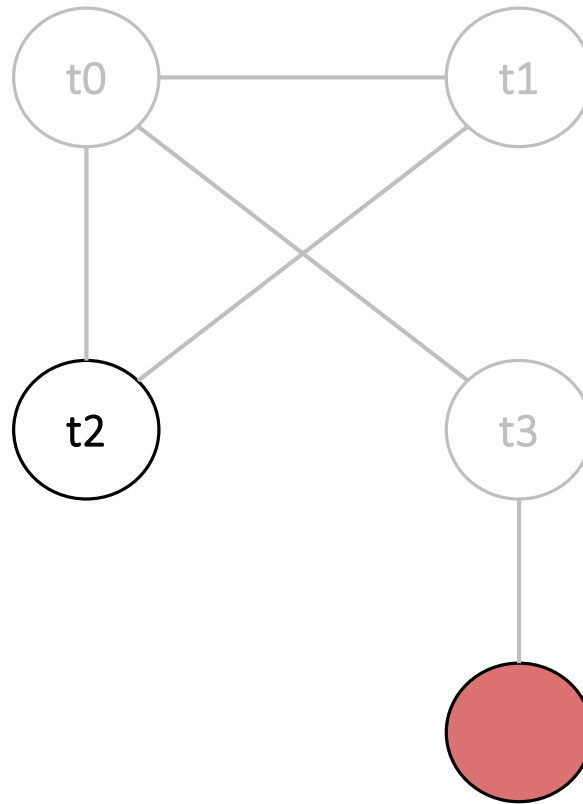
Graph Coloring



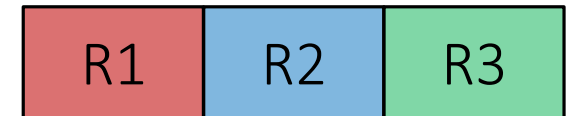
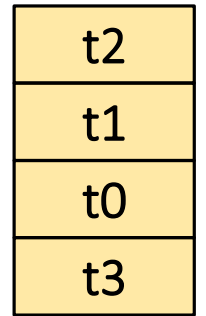
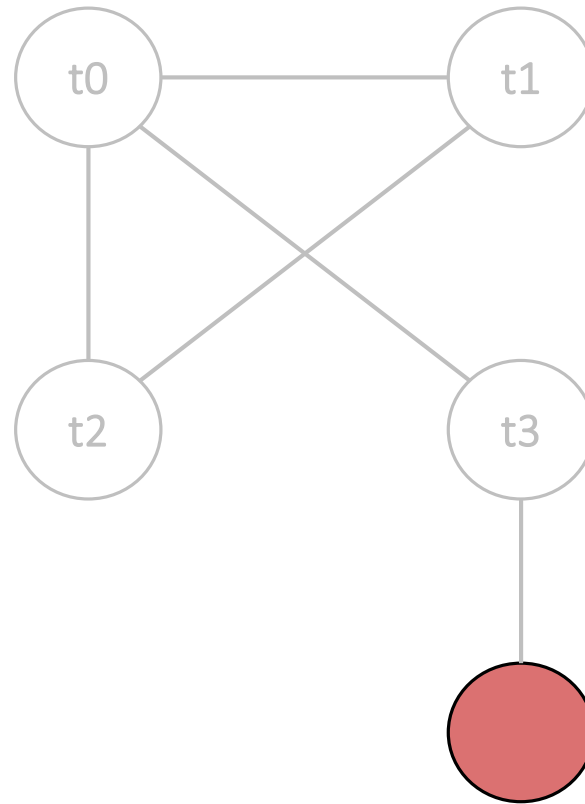
Graph Coloring



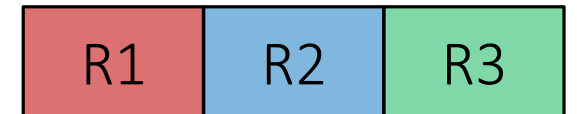
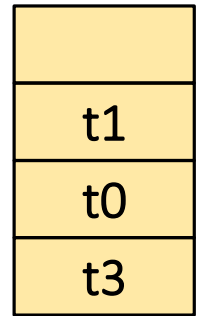
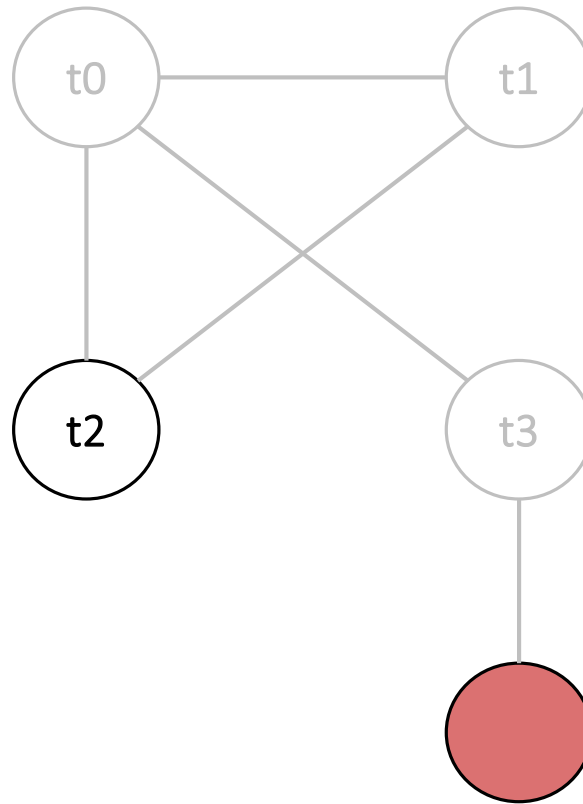
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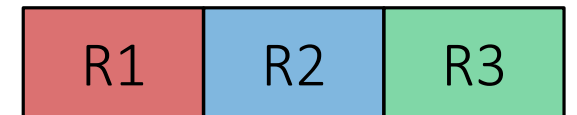
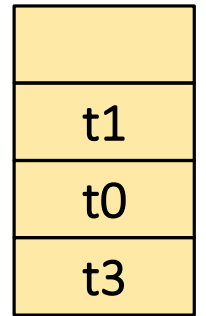
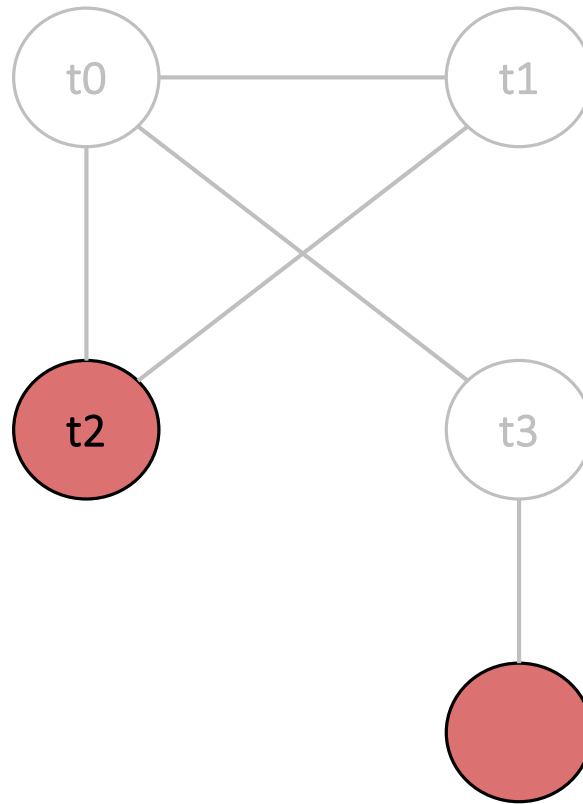
Graph Coloring



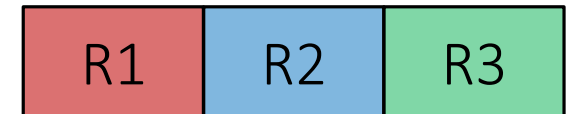
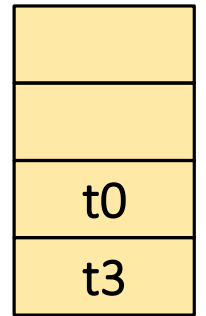
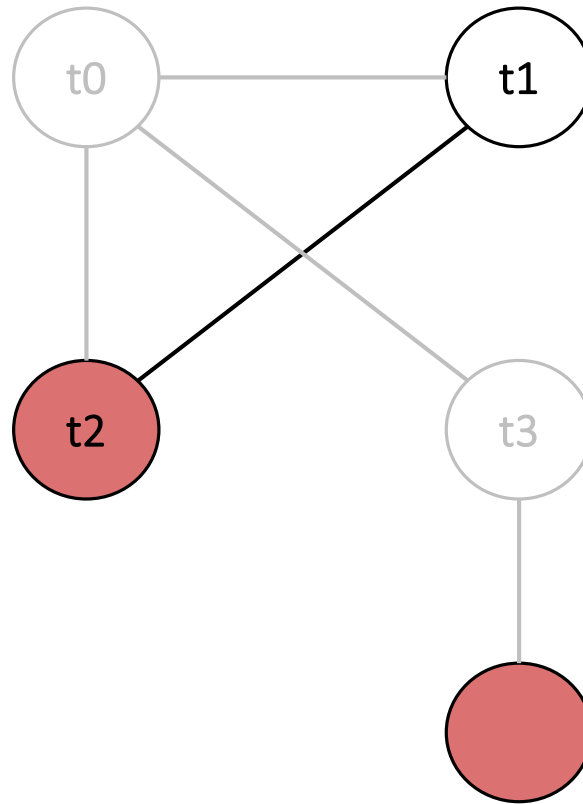
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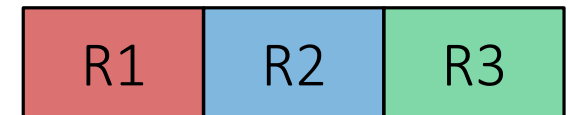
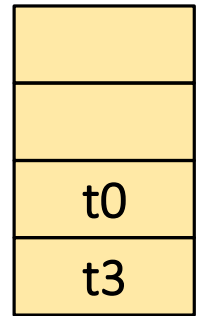
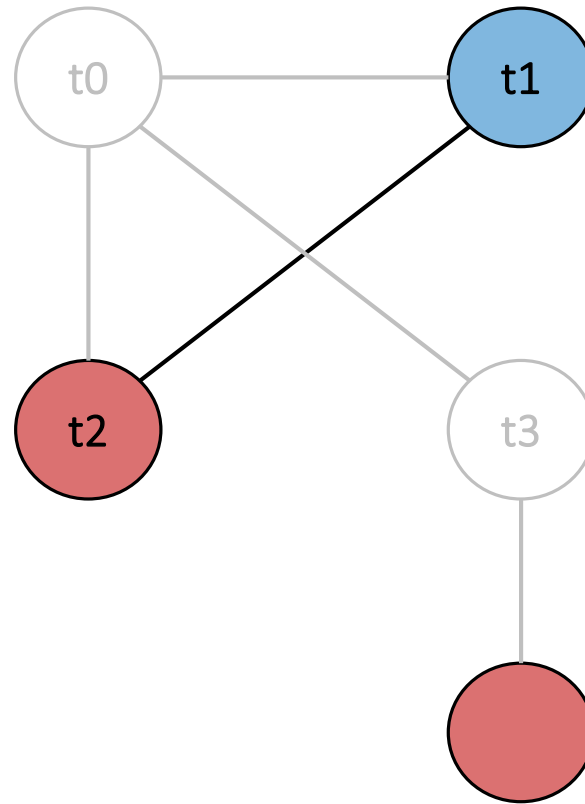
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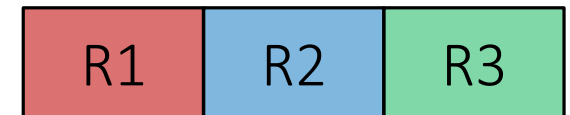
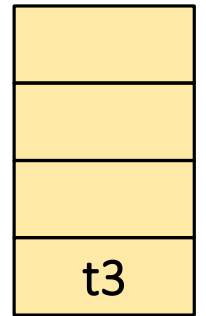
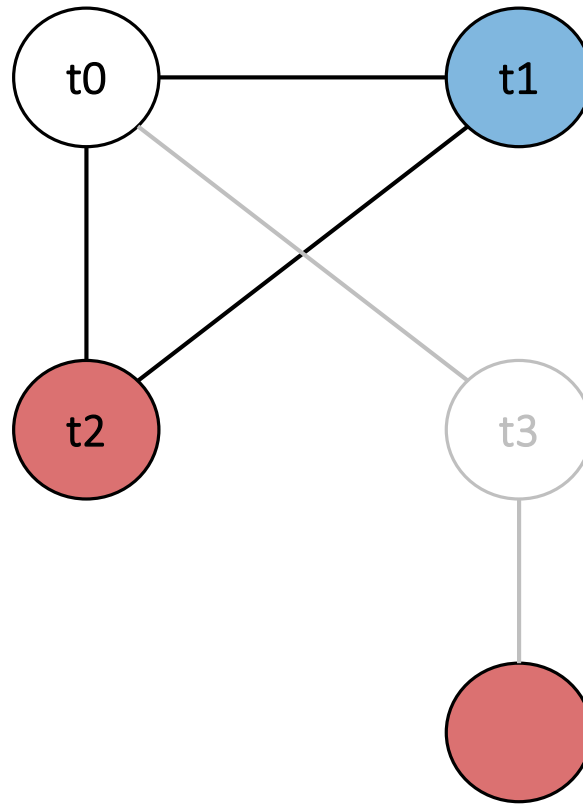
Graph Coloring



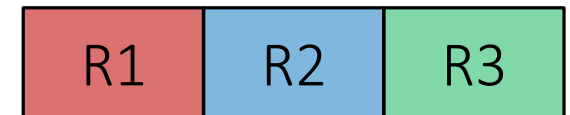
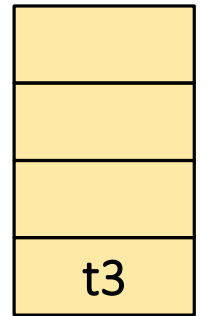
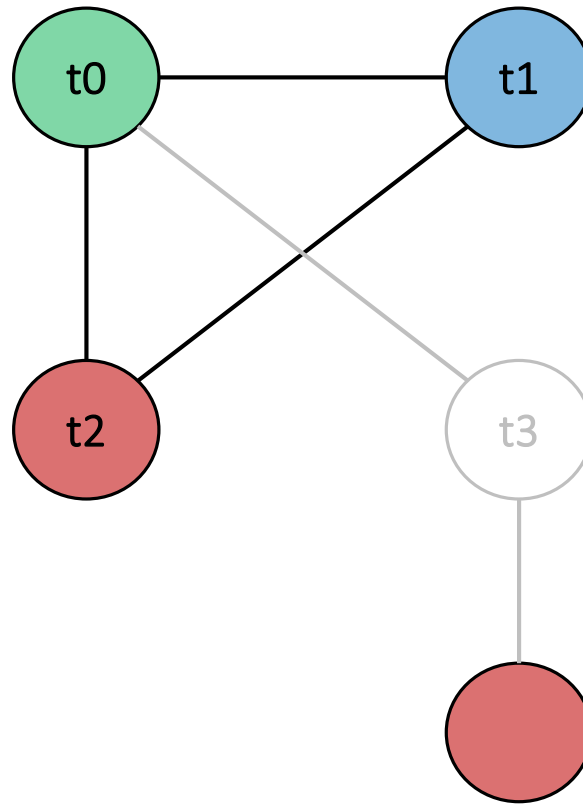
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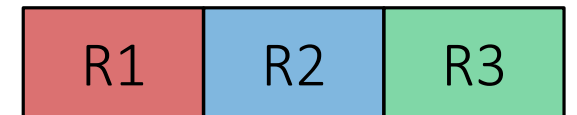
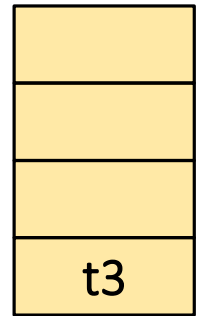
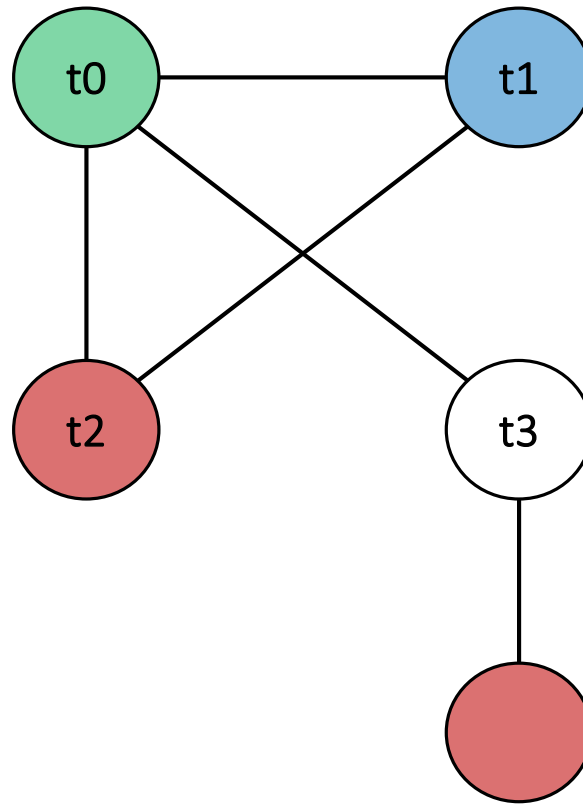
Graph Coloring



Graph Coloring



Graph Coloring



Graph Coloring

