

# CS738: Advanced Compiler Optimizations

## SSA Continued

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# Agenda

- ▶ Properties of SSA
- ▶ SSA to Executable
- ▶ SSA for Optimizations

# Complexity of Construction

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- ▶ Practical complexity:  $O(R)$

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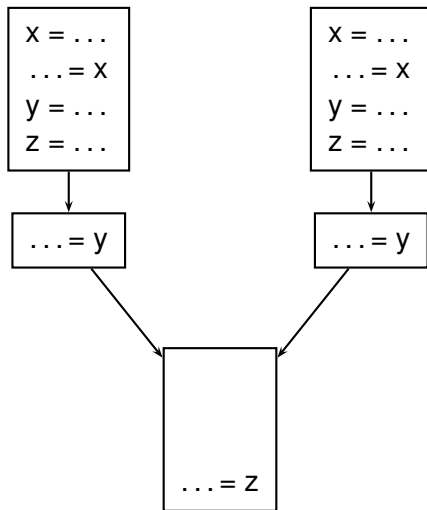
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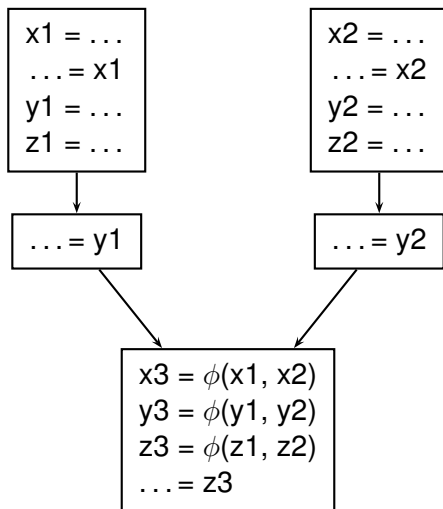
- ▶ By Sreedhar and Gao, in POPL'95
- ▶ Uses a new data structure called DJ-graph
- ▶ Linear time is achieved by careful ordering of nodes in the DJ-graph
- ▶ DF for a node is computed only once and reused later if required.

# Variants of SSA Form: Simple Example



Original Program

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Minimal SSA form



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- ▶ Semi-Pruned SSA

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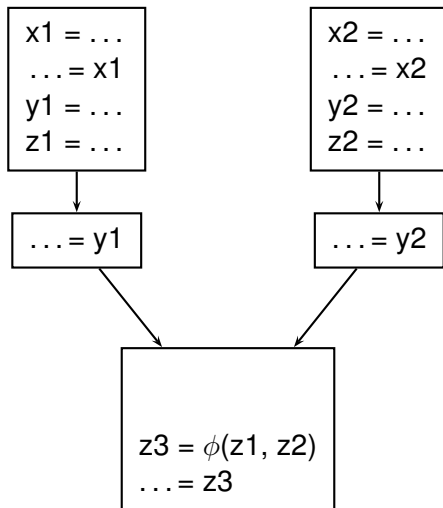
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## Variants of SSA Form: Pruned SSA Example



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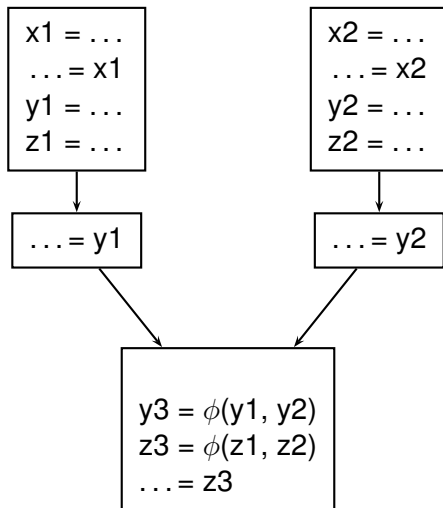
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- ▶ Non-locals can be computed without iteration or elimination

## Variants of SSA Form: Semi-pruned SSA Example



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        defined = defined  $\cup \{v\}$   
    }  
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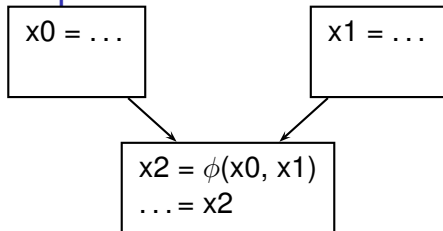
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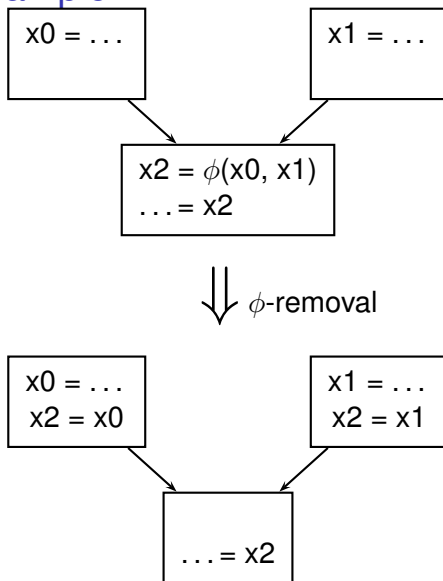
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  - ▶ Adds lots of copies
    - ▶ Many of them will be optimized by later passes

## $\phi$ -removal: Example

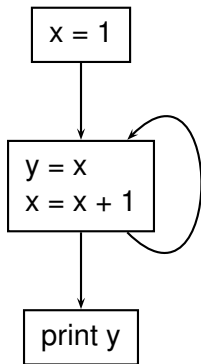




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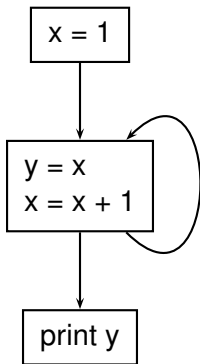


# Lost Copy Problem

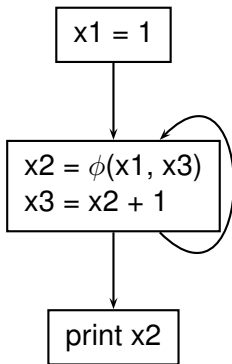


Program

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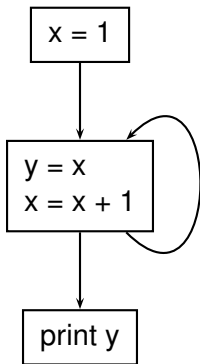


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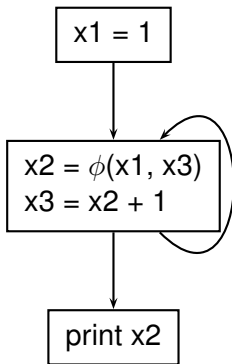


SSA from with  
copy propagation

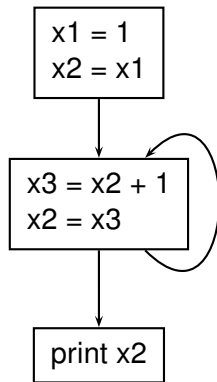
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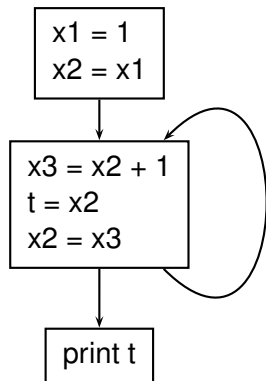


SSA form with  
copy propagation



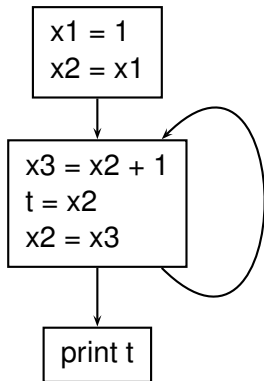
After  $\phi$ -removal

# Lost Copy Problem: Solutions

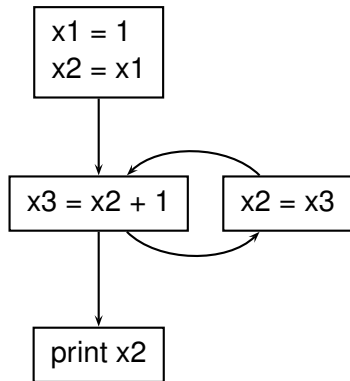


## 1. Use of Temporary

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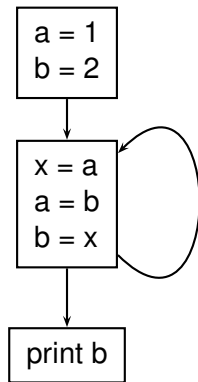


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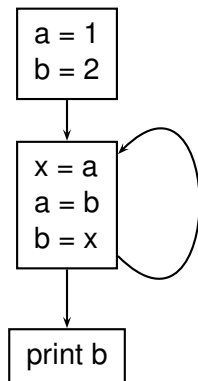
2. Critical Edge Split

# Swap Problem

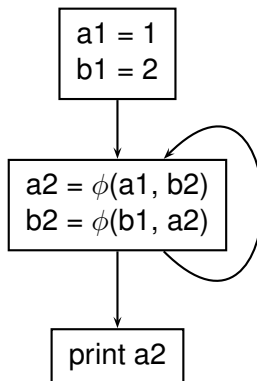


Program

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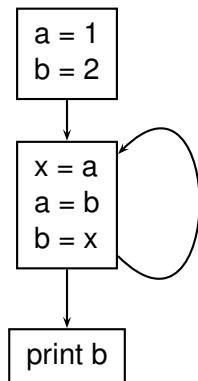
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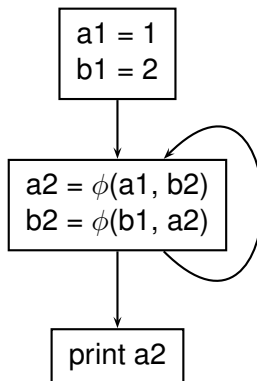
SSA form with  
copy propagation



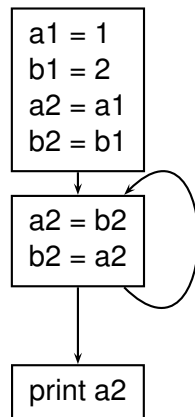
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Program



SSA form with  
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After  $\phi$ -removal

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- ▶ May require temporary if cyclic dependency exists.

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