SuperGraph-SLP Auto-Vectorization

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Intel

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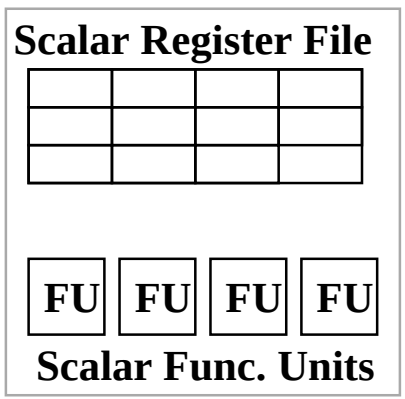
Notice revision #20110804

Why SIMD Vectorization?

- Scalable parallelism (compared to ILP)



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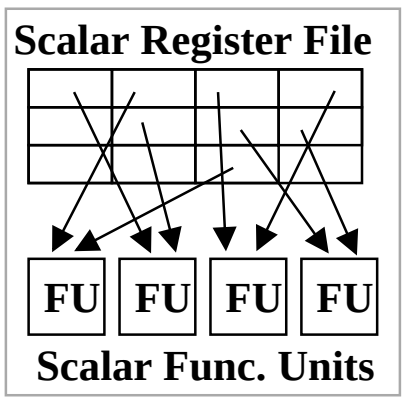

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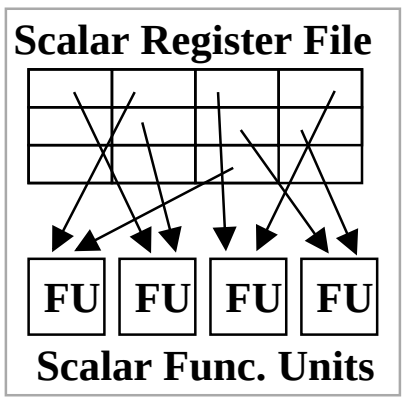

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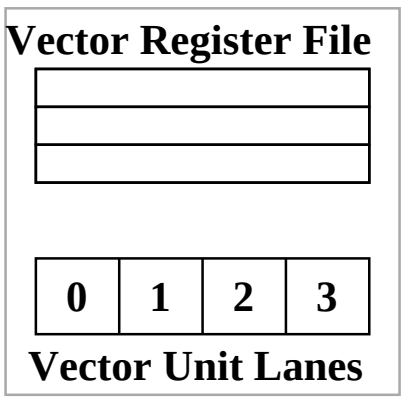

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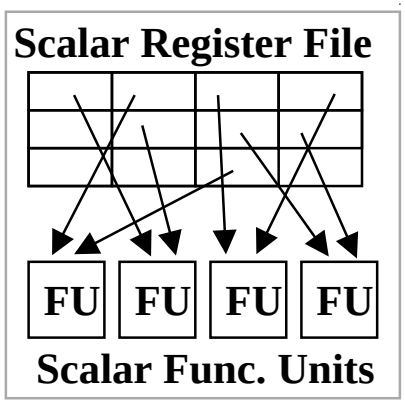

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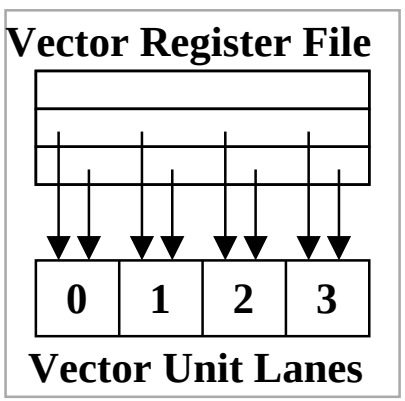

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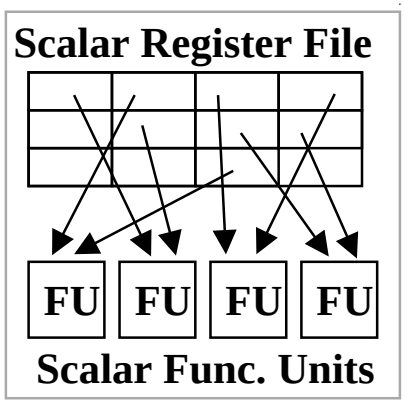

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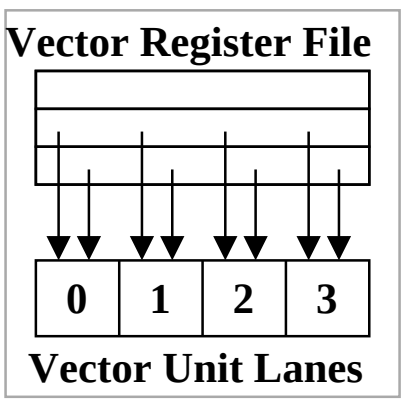

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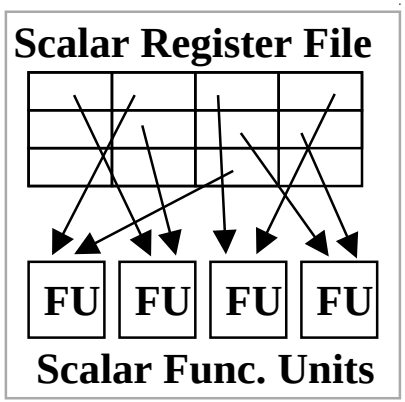

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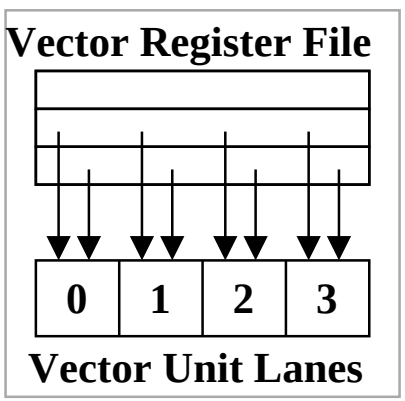

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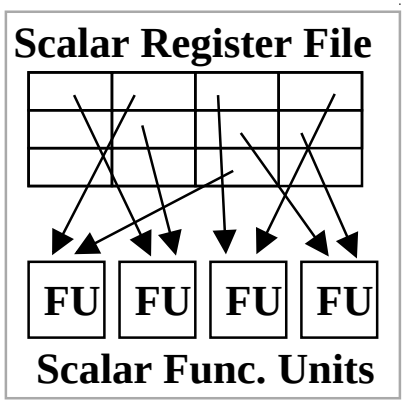

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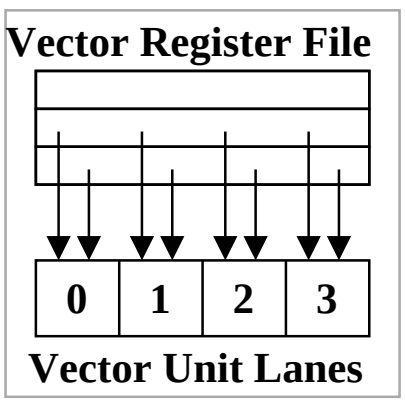

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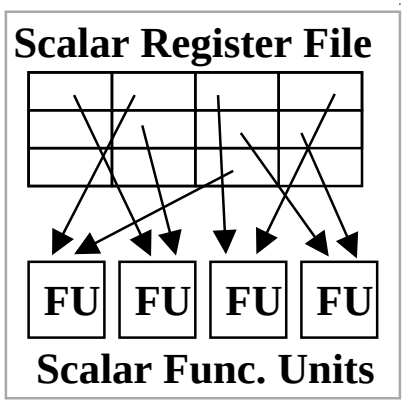

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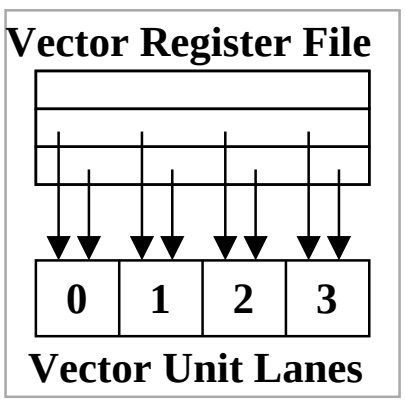

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  - Even if loop-vectorizer fails, SLP could partly succeed
- It is missing features present in the Loop vectorizer (e.g., Interleaved Loads, Predication)
  - Usually run SLP after the Loop Vectorizer

SLP is usually good enough

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tmp1 = B[i+0] + D[i+0];
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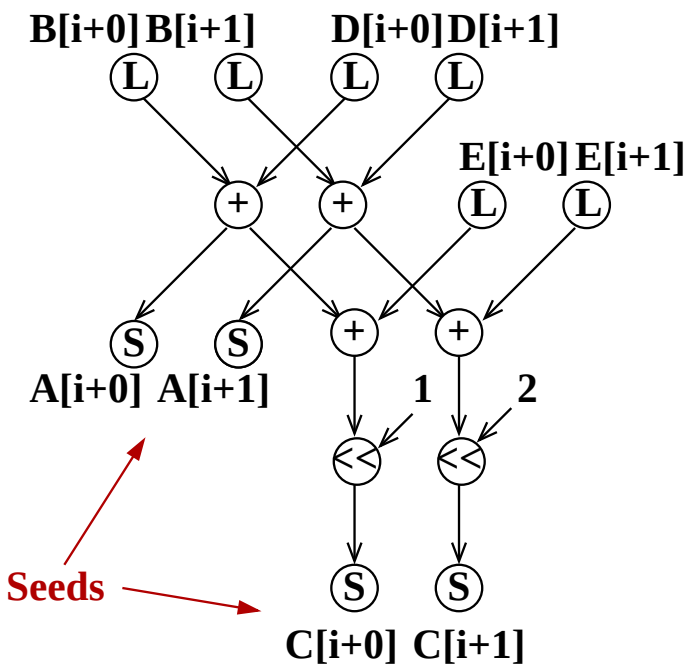

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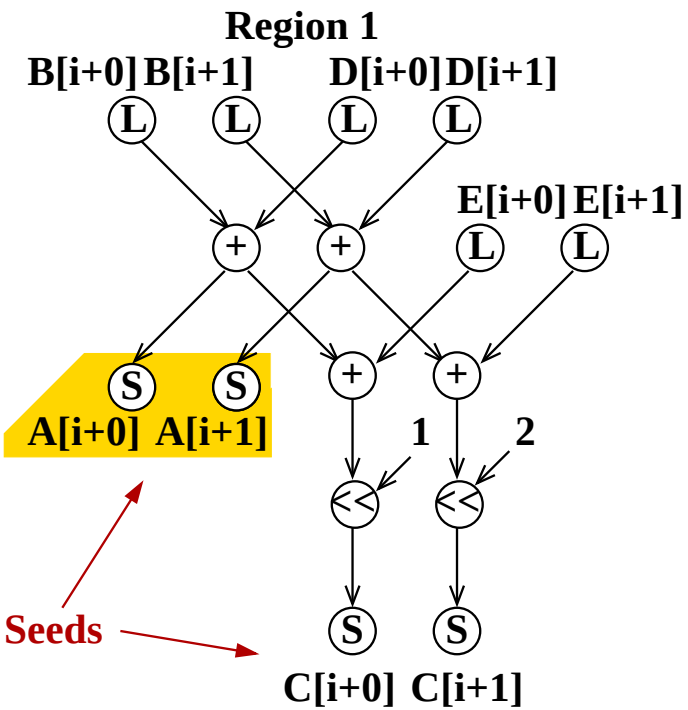

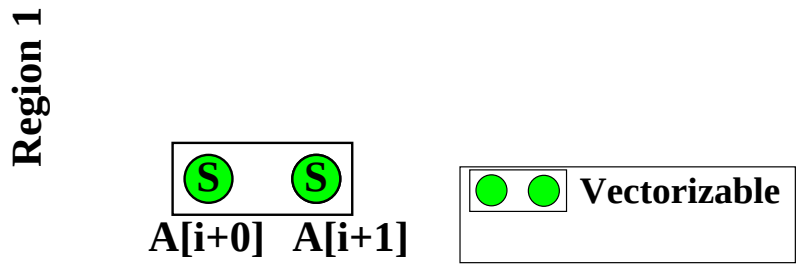

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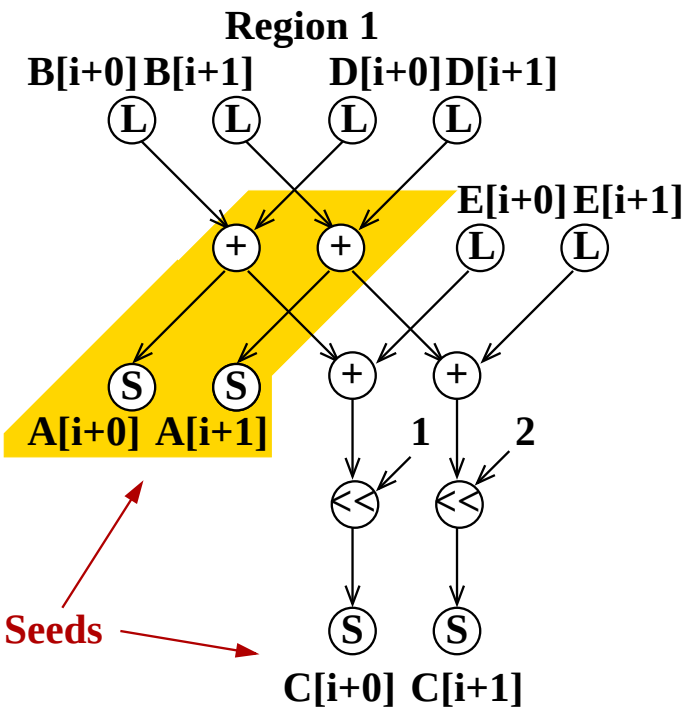

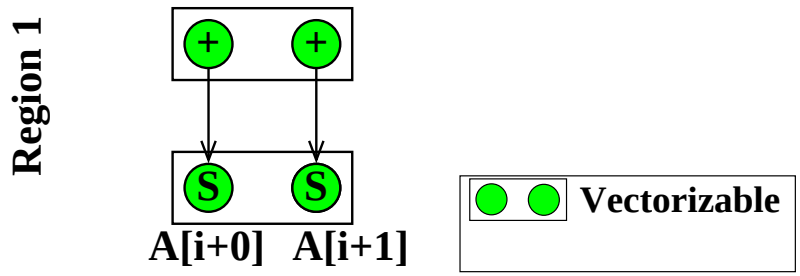

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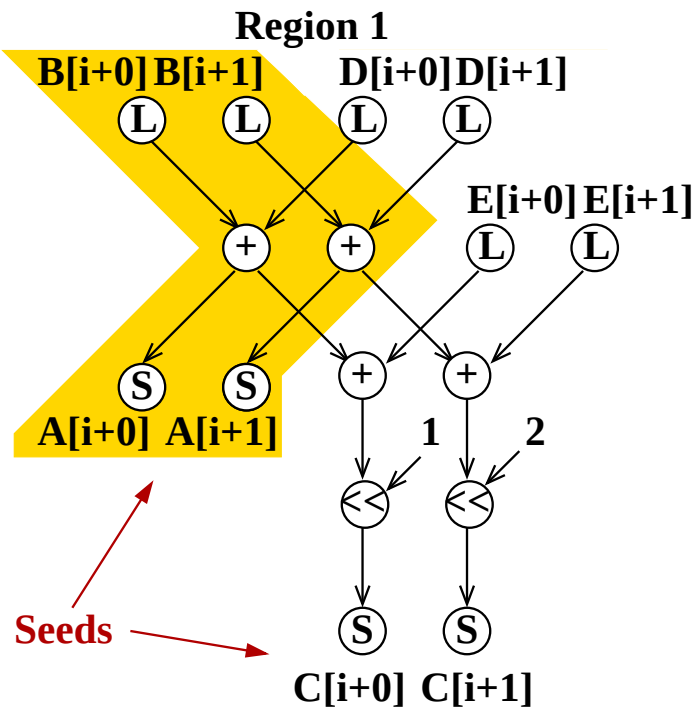

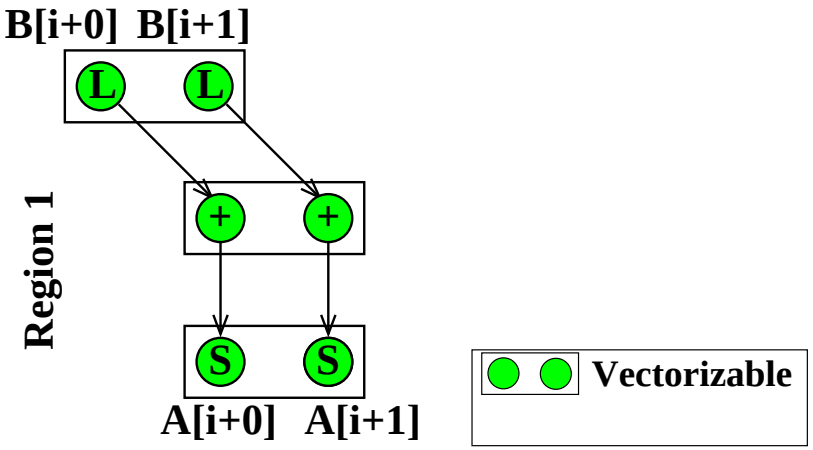

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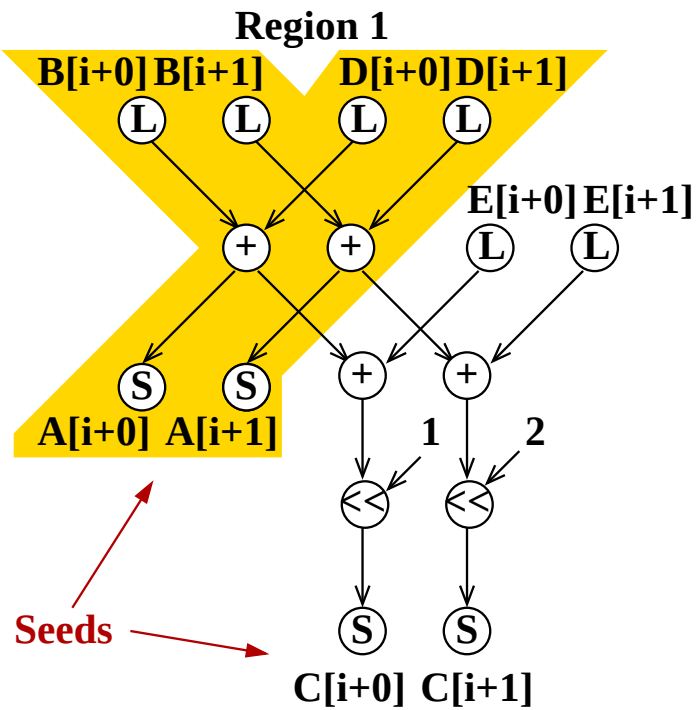

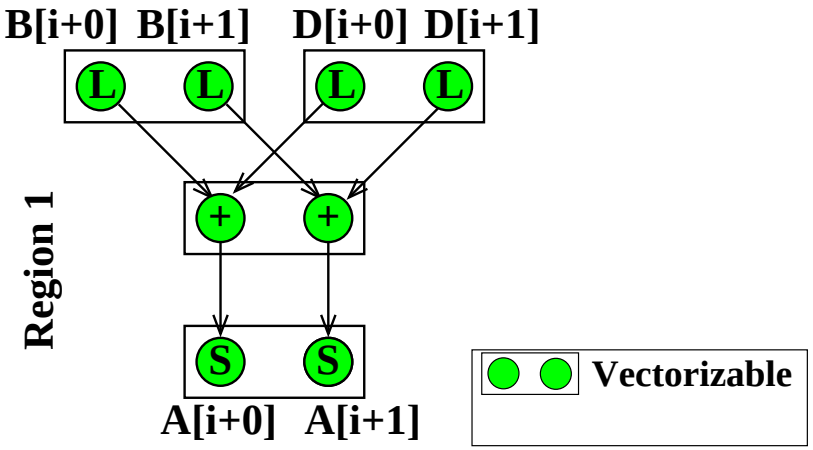

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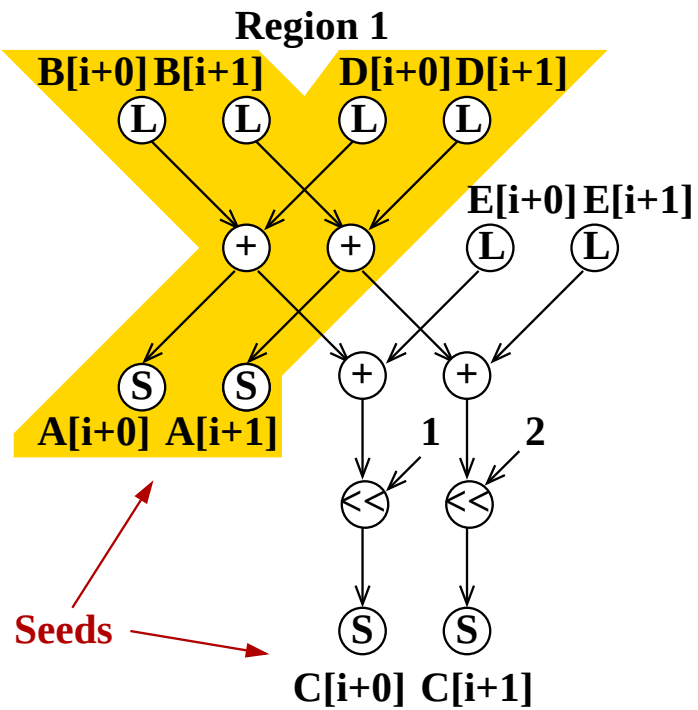

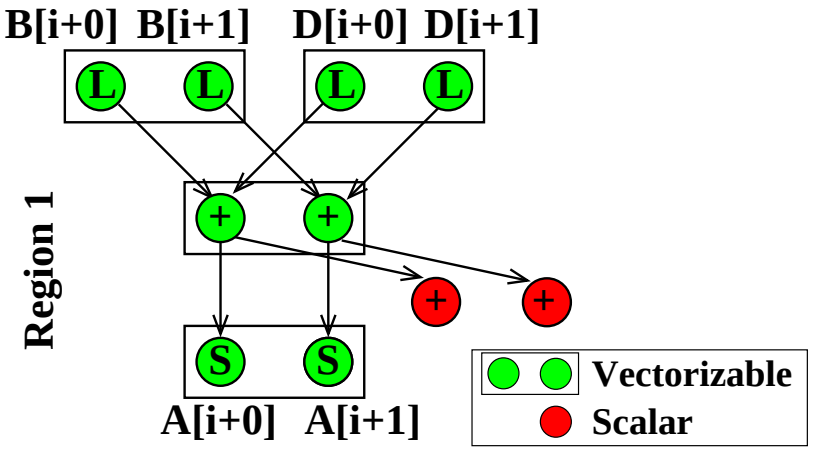

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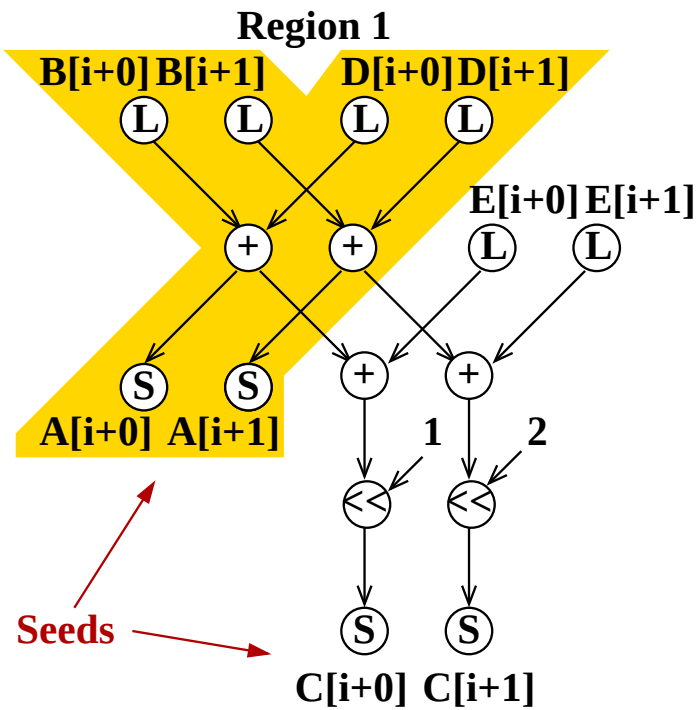

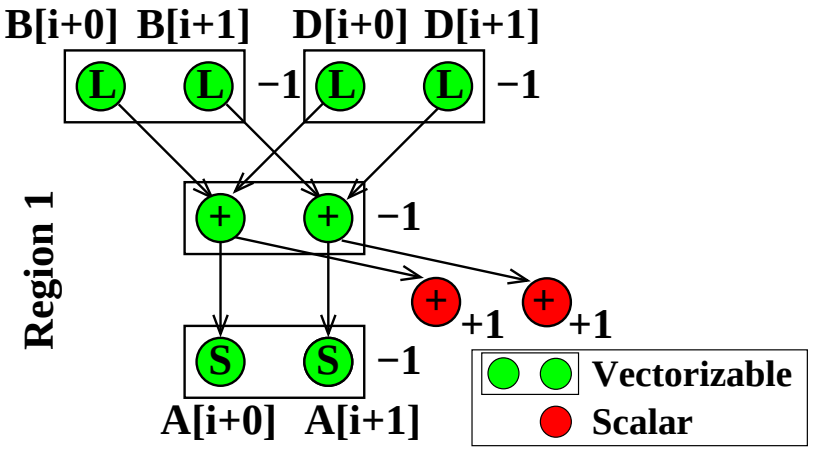

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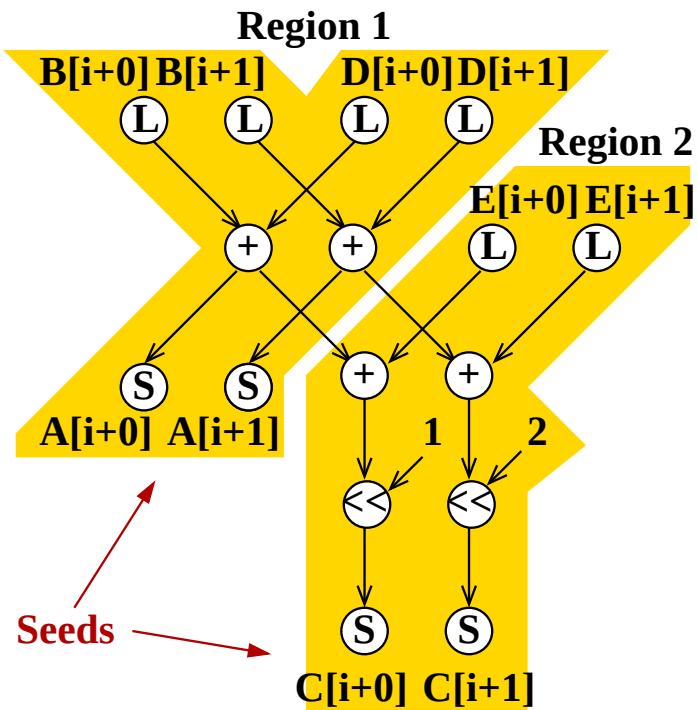

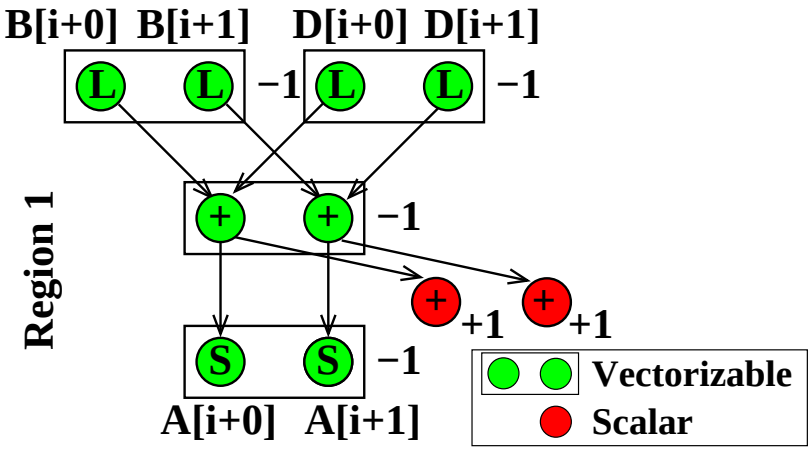

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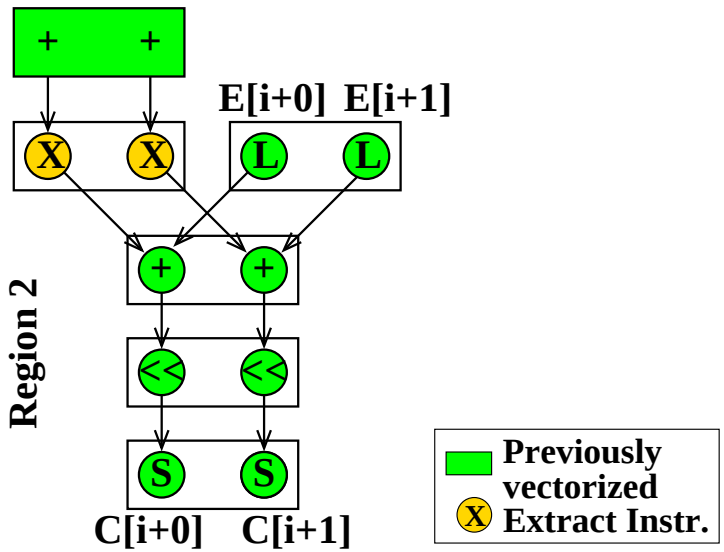

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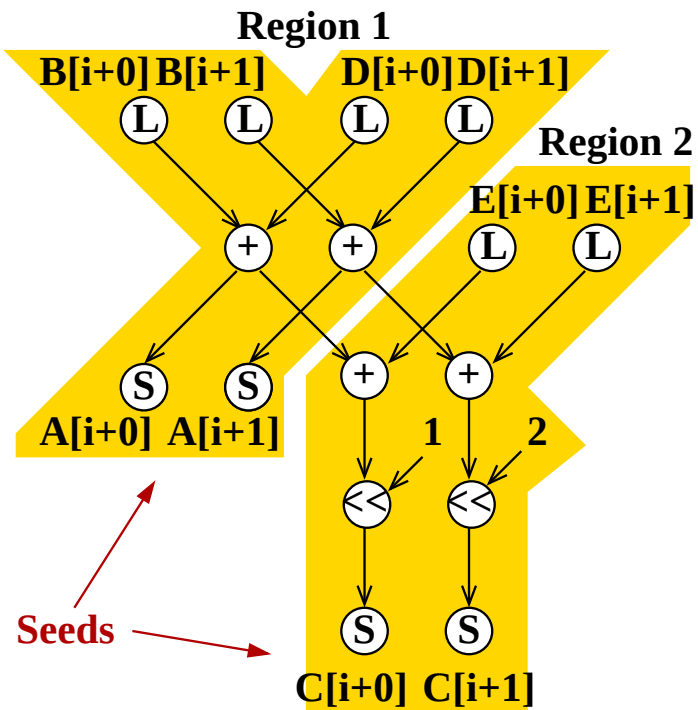

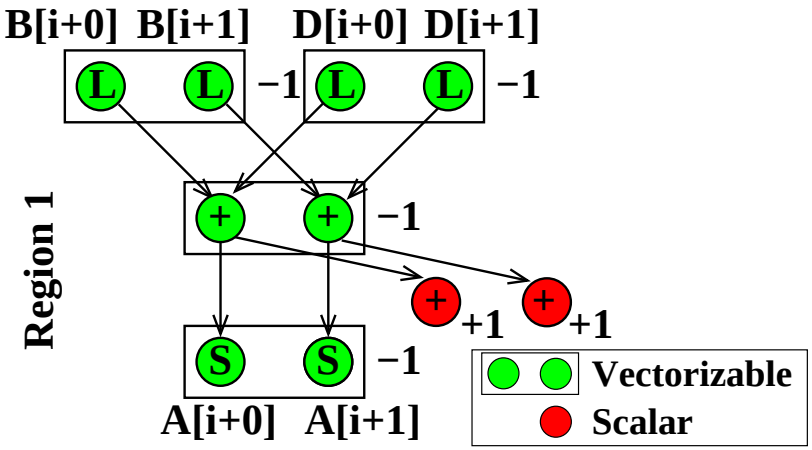

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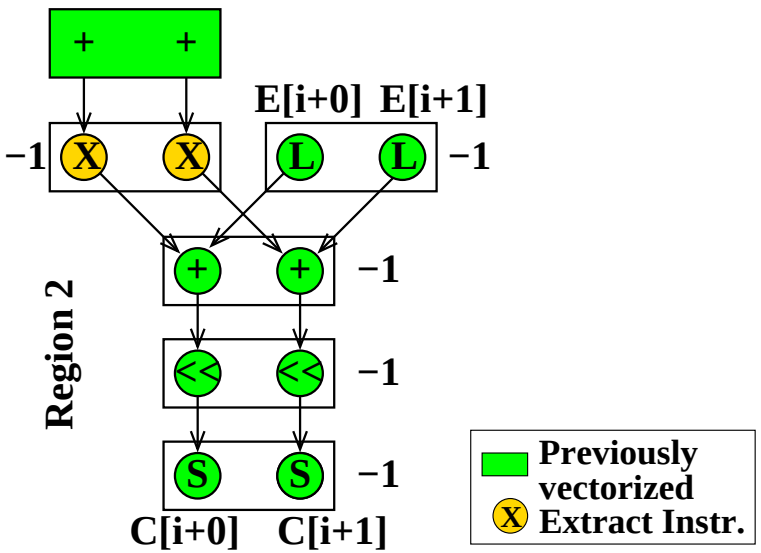

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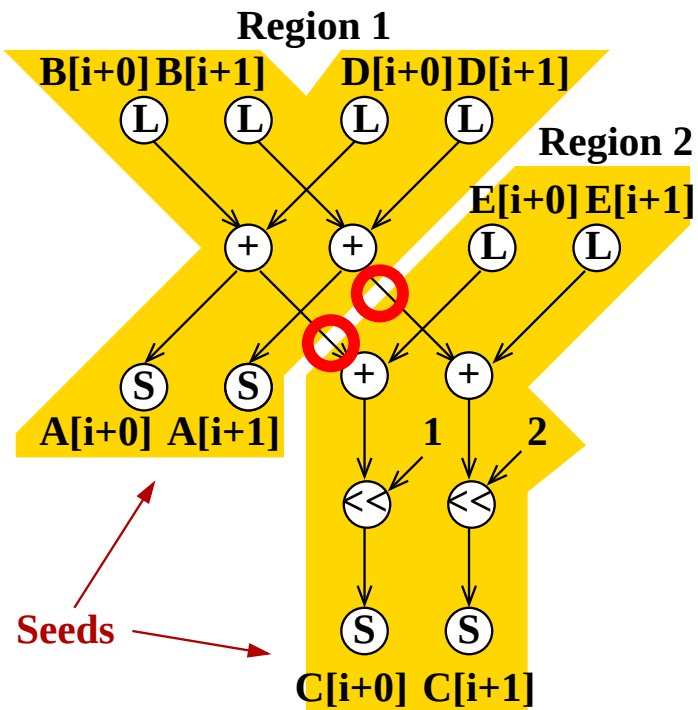

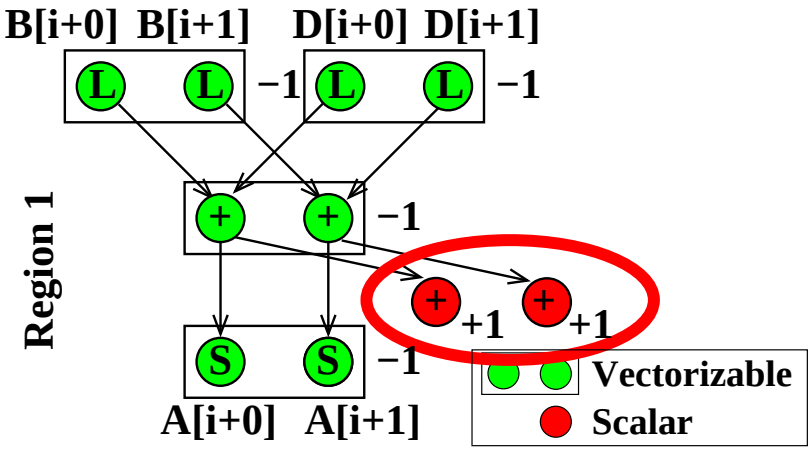

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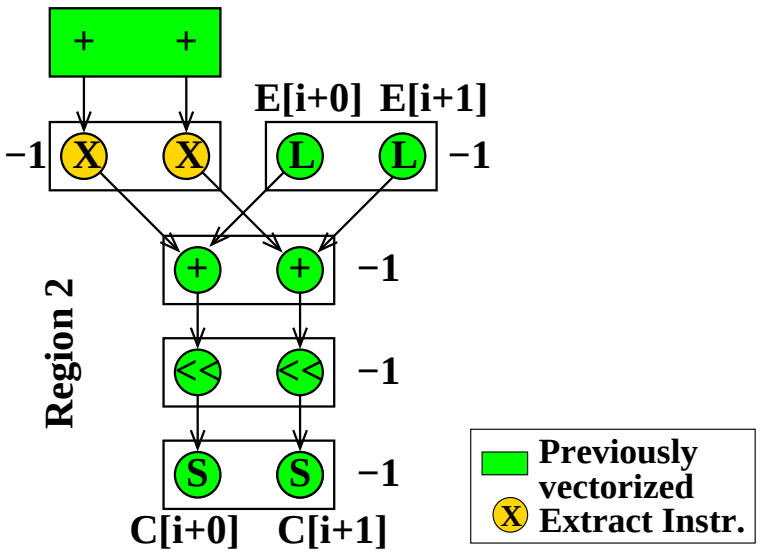

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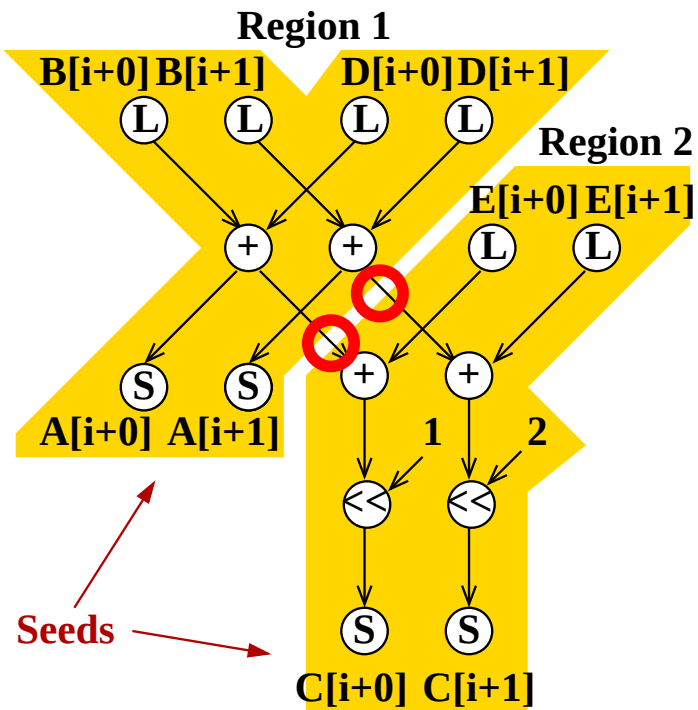

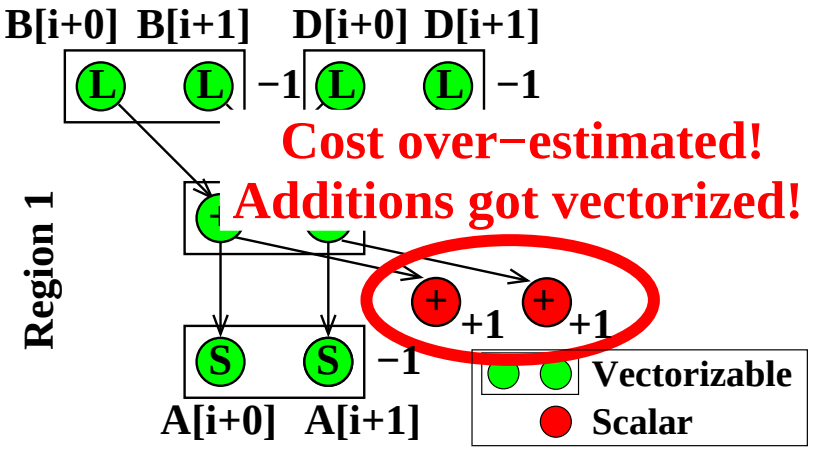

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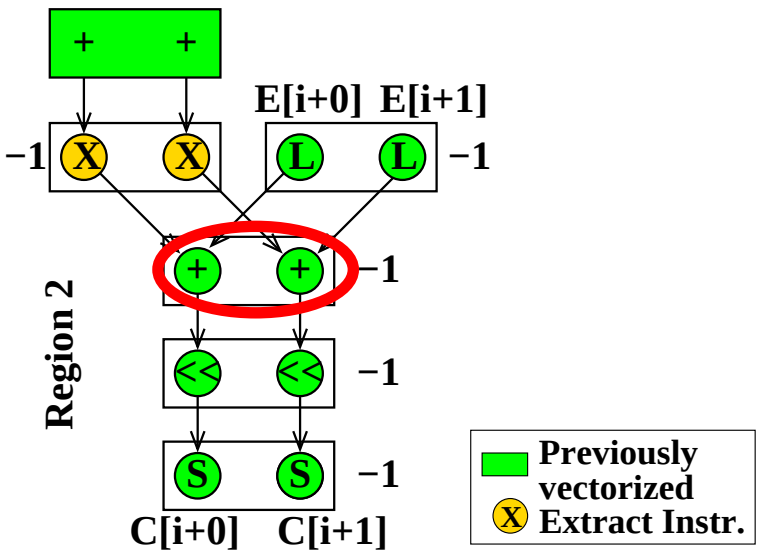

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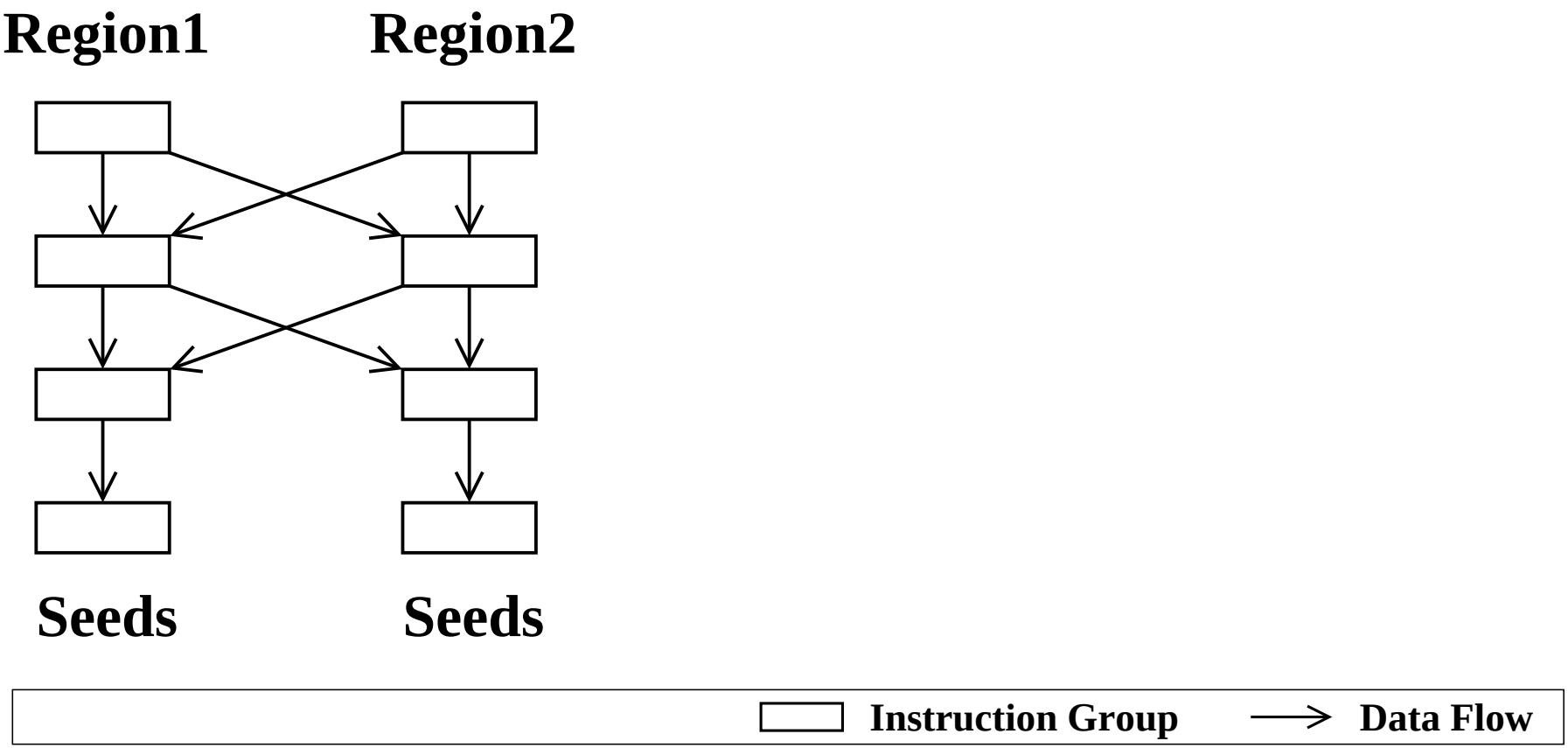
Super-Graph SLP: Larger Unified Region



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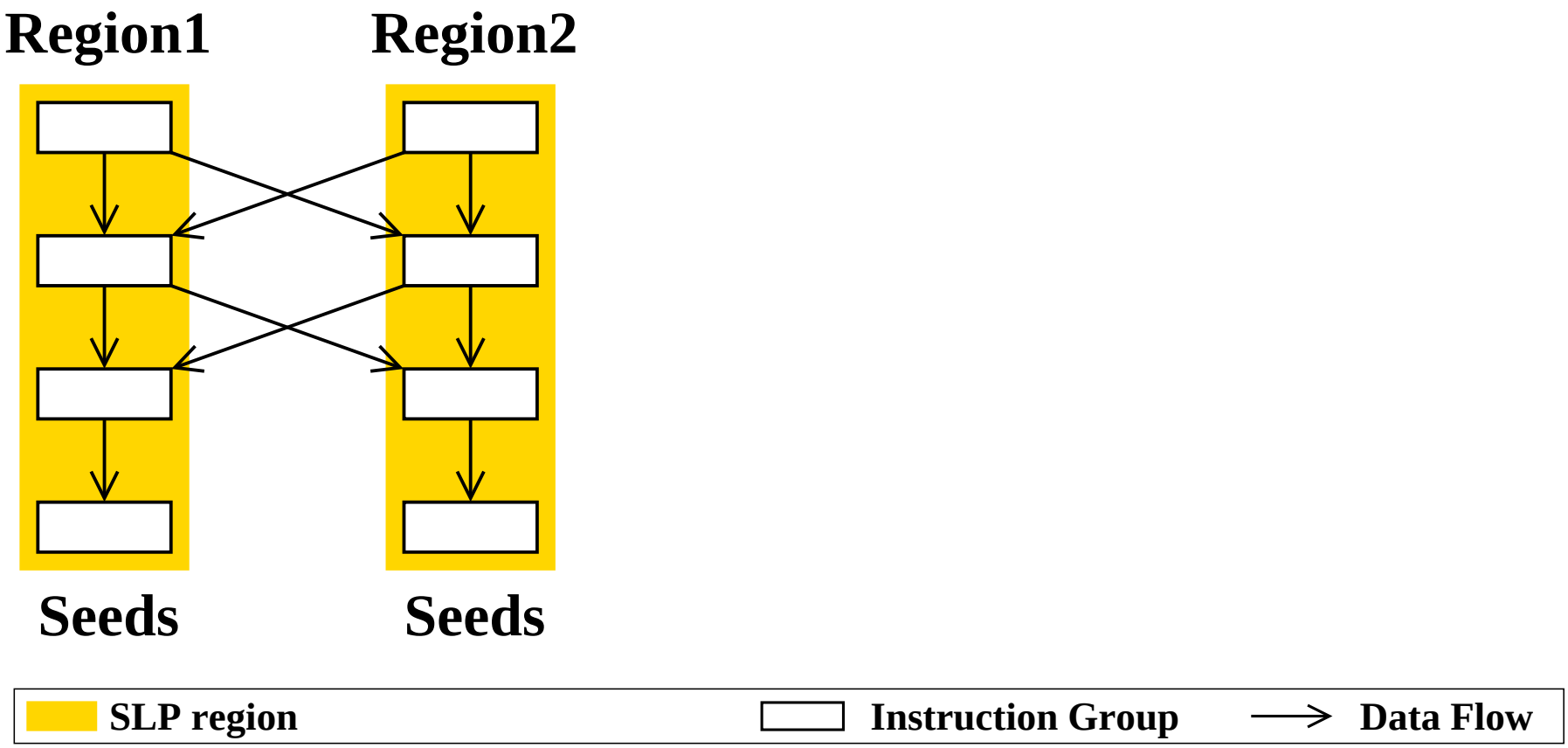
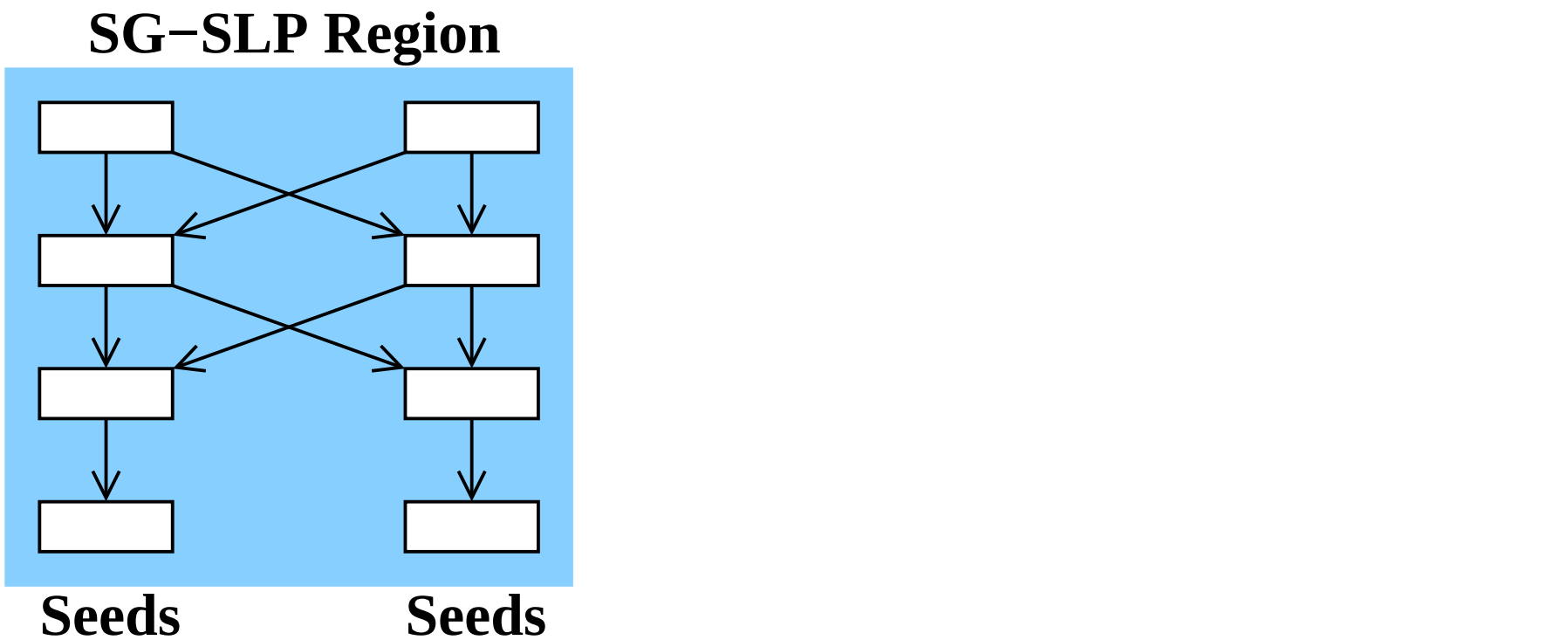


1. Cross-region dependencies

Super-Graph SLP: Larger Unified Region



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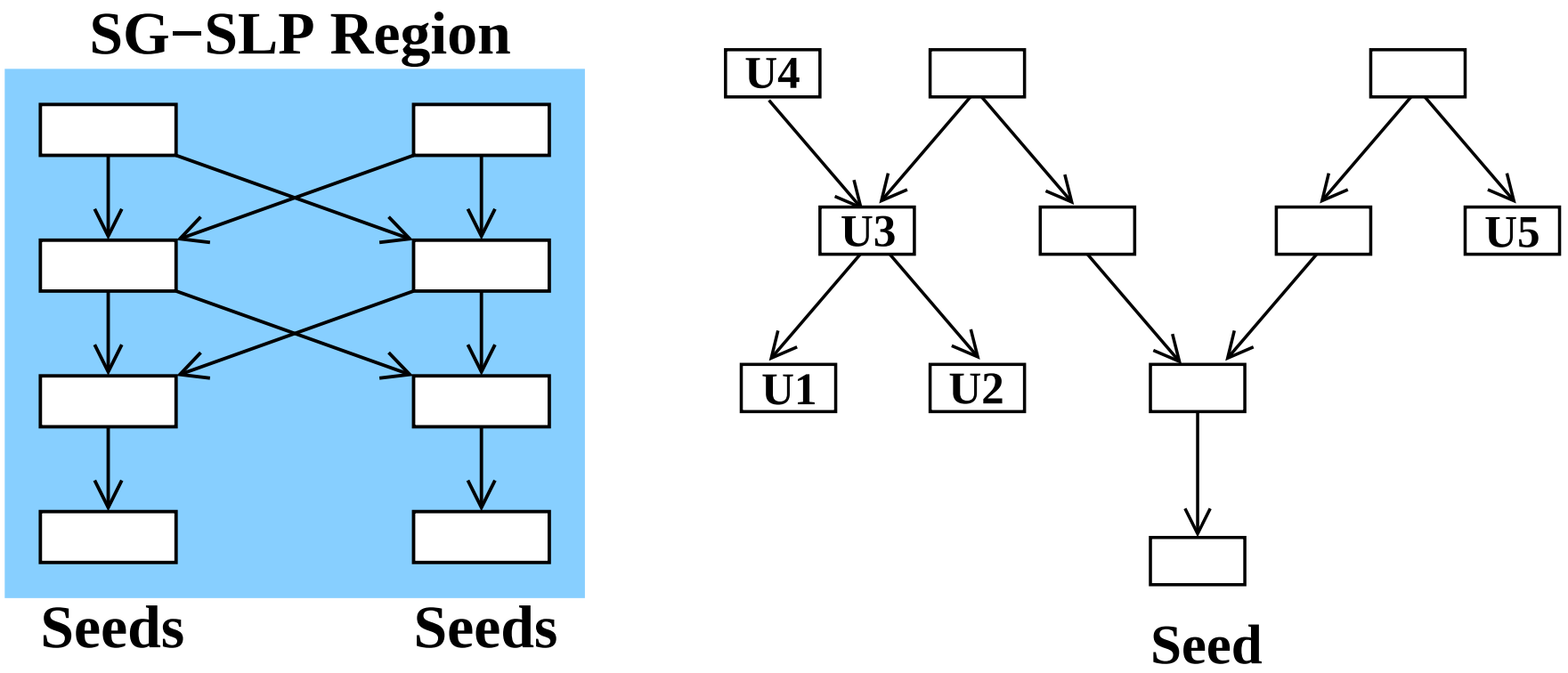
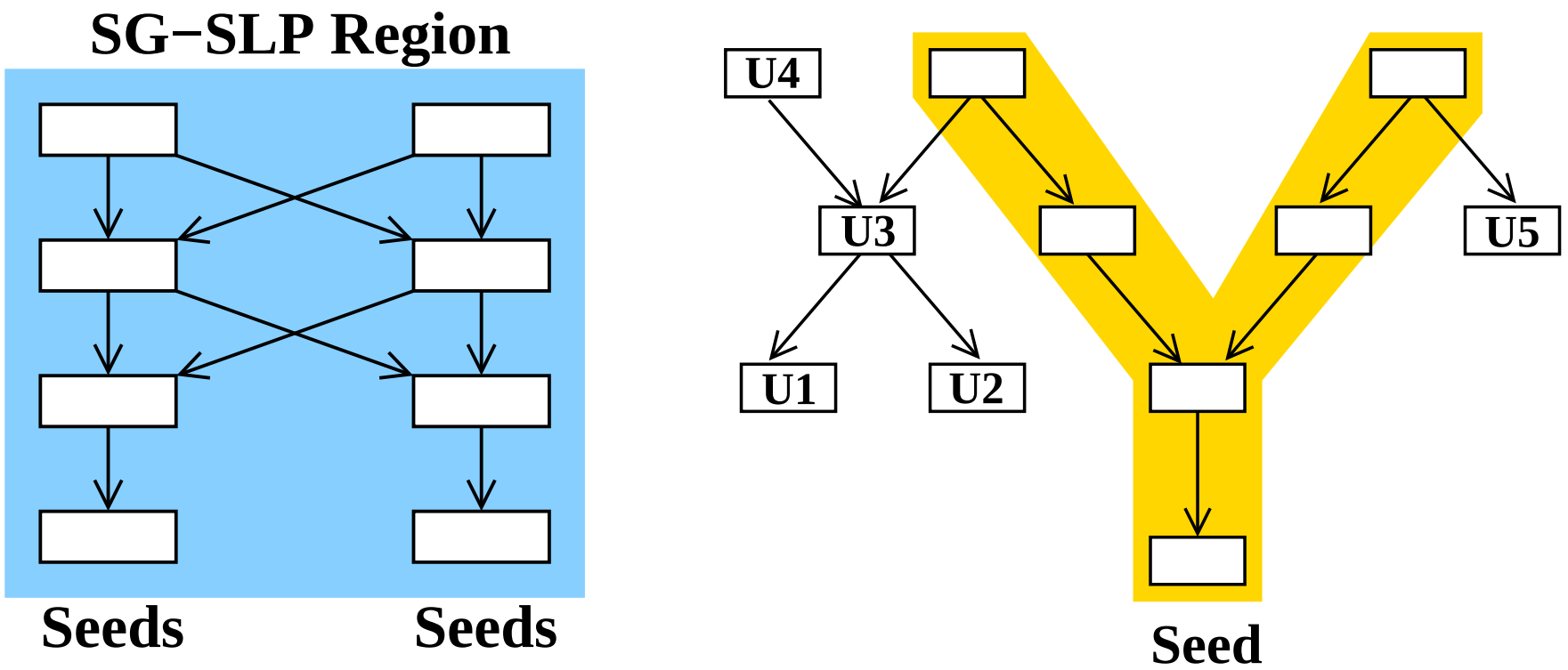
Super-Graph SLP: Larger Unified Region



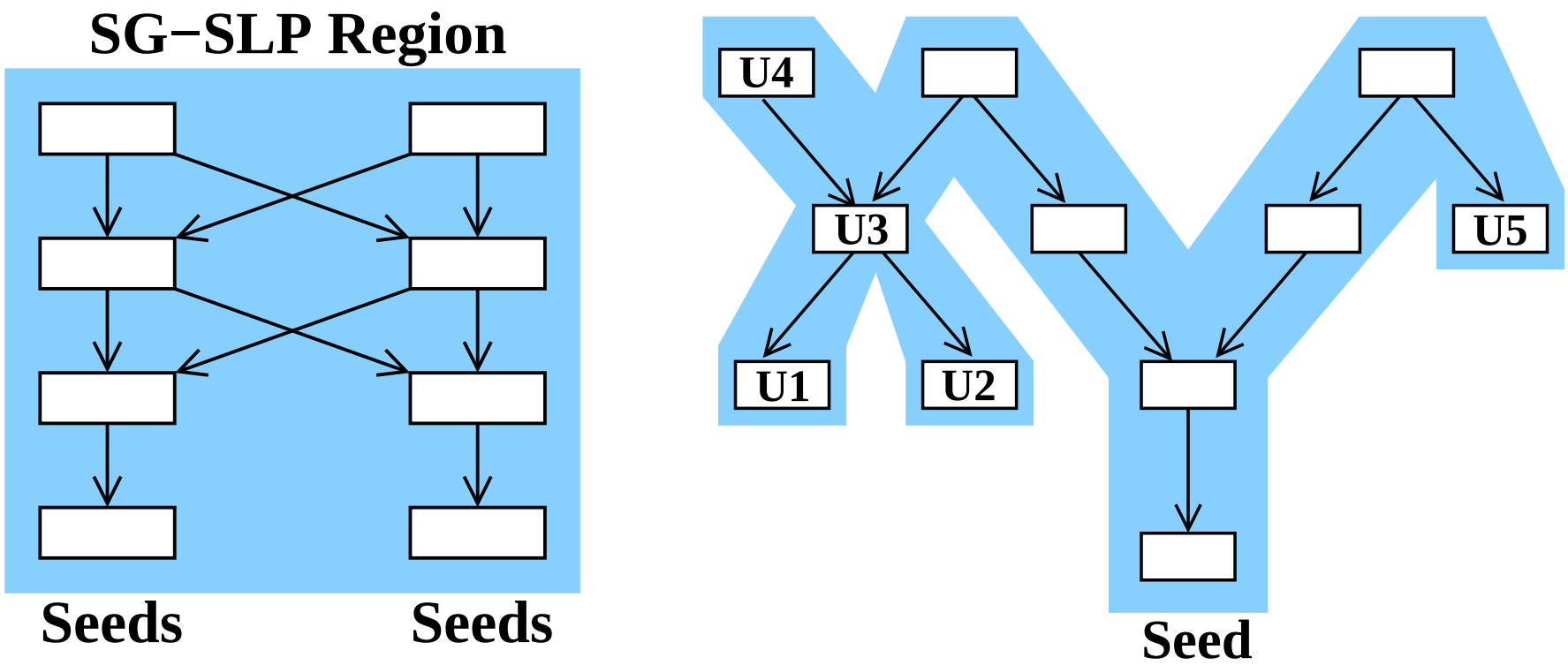
1. Cross-region dependencies

Super-Graph SLP: Larger Unified Region



1. Cross-region dependencies
2. Unreachable instructions by SLP

Super-Graph SLP: Larger Unified Region



1. Cross-region dependencies
2. Unreachable instructions by SLP

1. SLP Fails due to Cross-Region Dependencies

```
long tmp1, tmp2, A[], B[], C[];
tmp1 = B[i+0];
tmp2 = B[i+1];
A[i+0] = tmp1;
A[i+1] = tmp2;
C[i+0] = tmp1;
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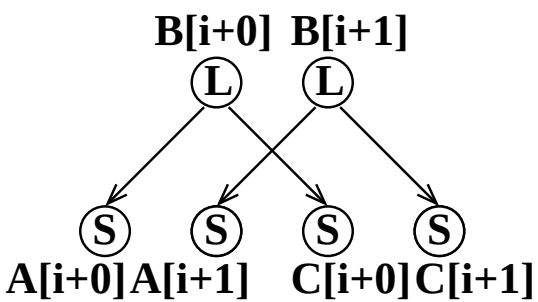

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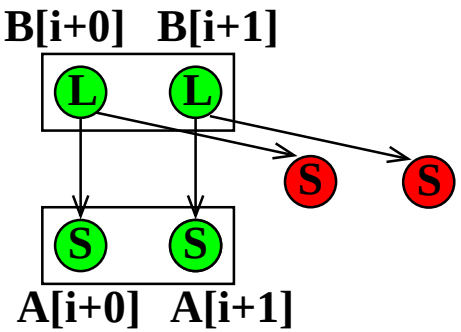
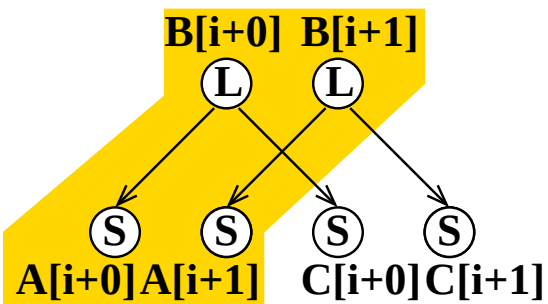
SLP





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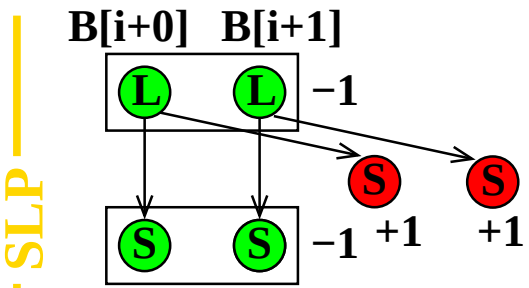
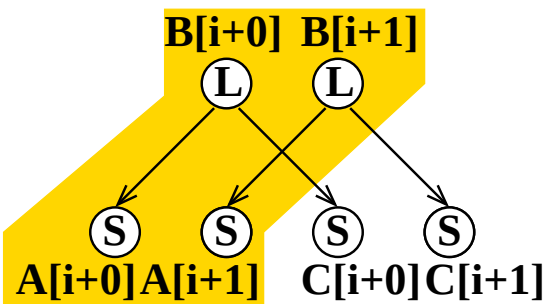
SLP



Total Cost: 0

NOT VECTORIZED



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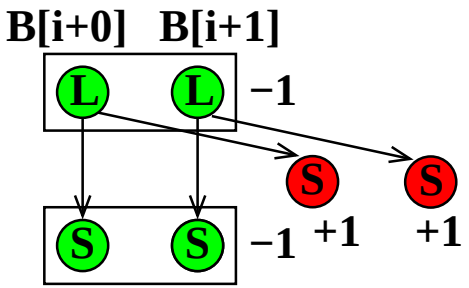
SLP



Total Cost: 0

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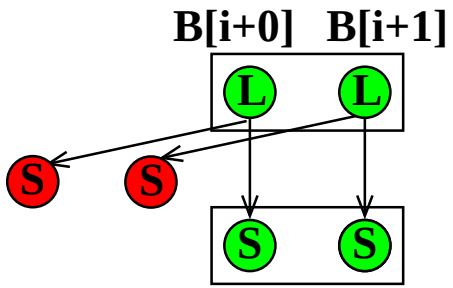

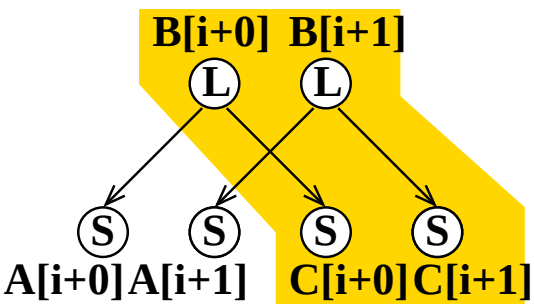

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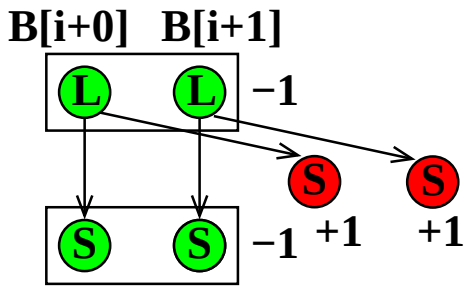
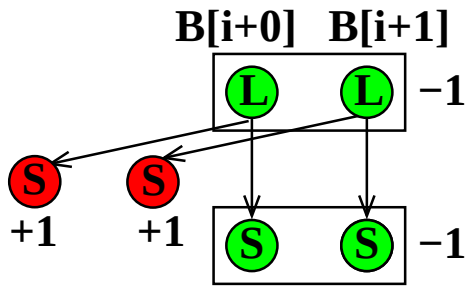
SLP



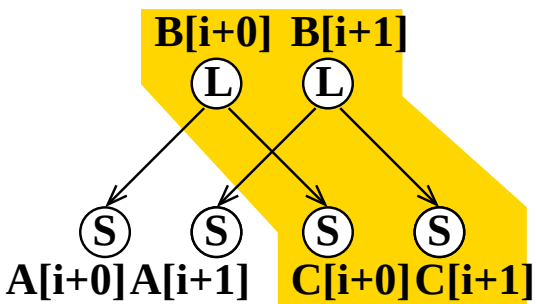
Total Cost: 0

NOT VECTORIZED



Total Cost: 0

NOT VECTORIZED



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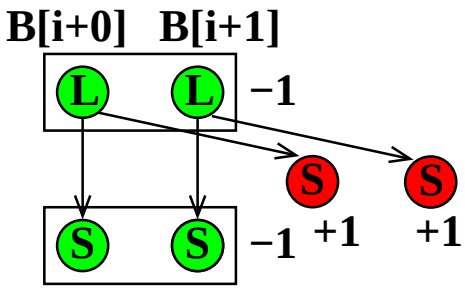
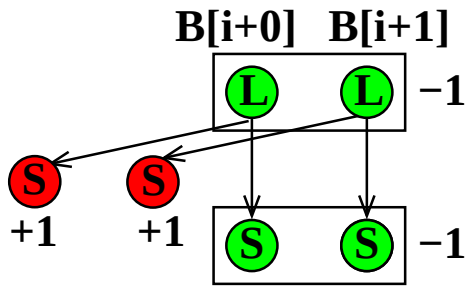
SLP



Total Cost: 0

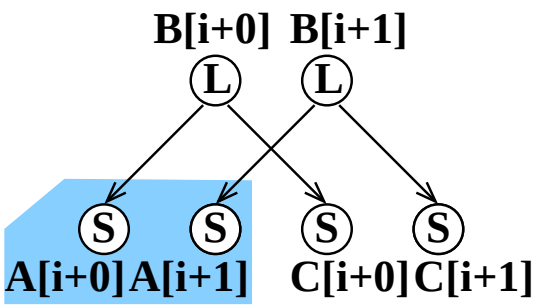
NOT VECTORIZED

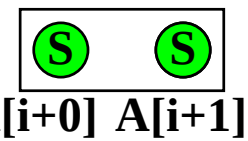


Total Cost: 0

NOT VECTORIZED

SG–SLP





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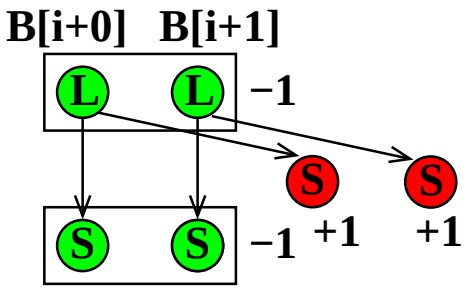
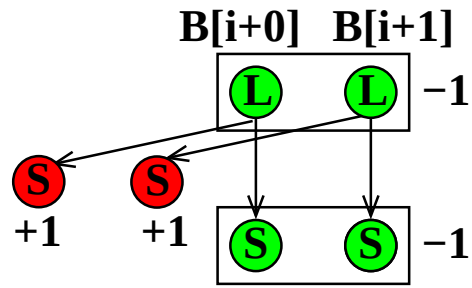
SLP



Total Cost: 0

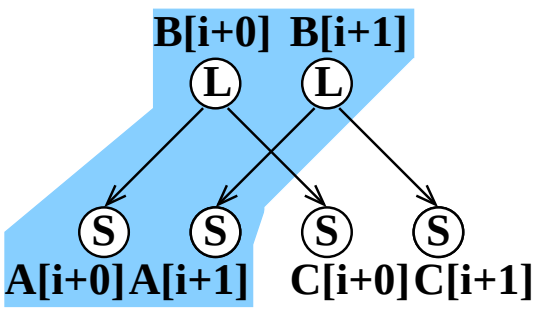
NOT VECTORIZED

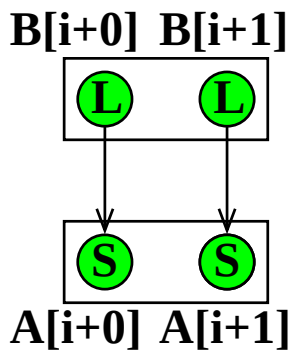


Total Cost: 0

NOT VECTORIZED

SG–SLP





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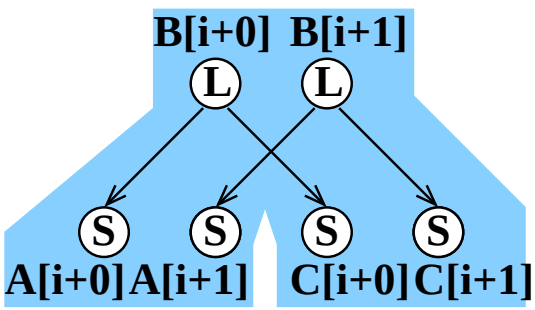
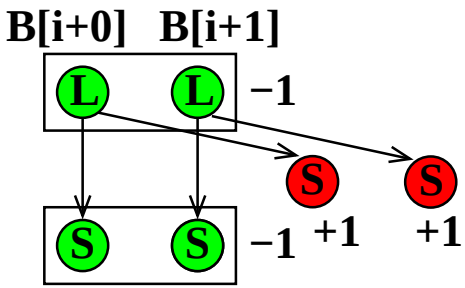
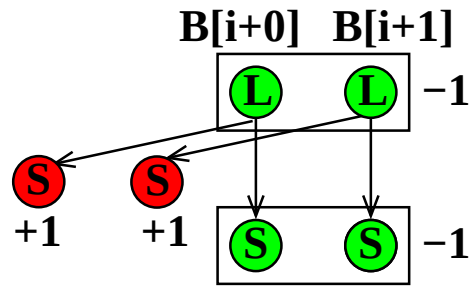


SLP



Total Cost: 0

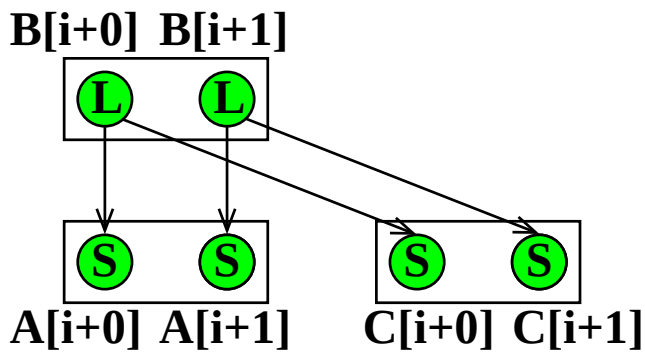
NOT VECTORIZED



Total Cost: 0

NOT VECTORIZED

SG–SLP



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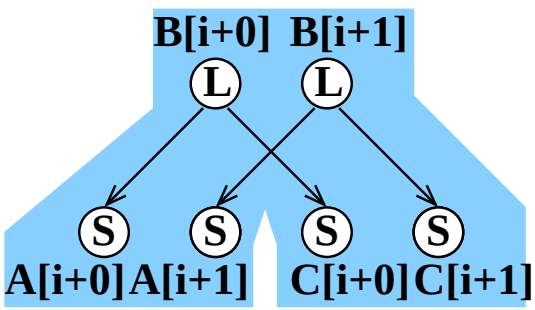
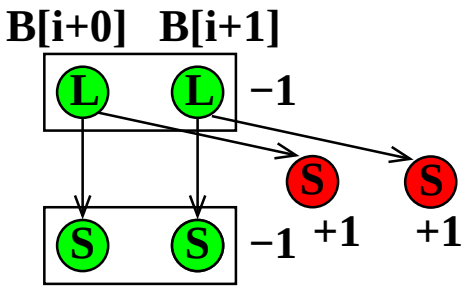
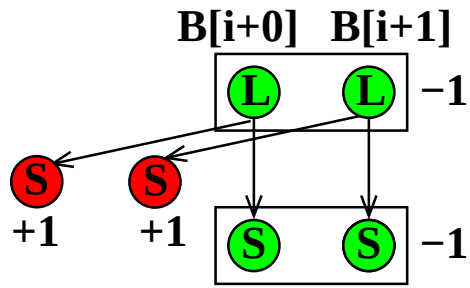


SLP



Total Cost: 0

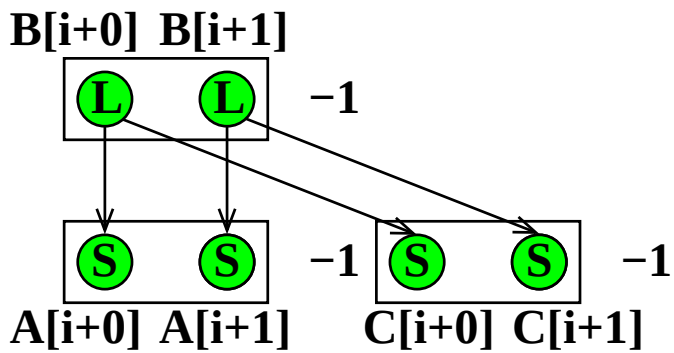
NOT VECTORIZED



Total Cost: 0

NOT VECTORIZED

SG–SLP



Total Cost: −3 VECTORIZED !

2. SLP Fails due to Unreachable Instructions

```
long tmp1, tmp2, A[], B[], C[], D[], E[];
tmp1 = B[i+0] + D[i+0];
tmp2 = B[i+1] + D[i+1];
A[i+0] = tmp1;
A[i+1] = tmp2;
C[i+x] = (tmp1 + E[i+0]) << 1;
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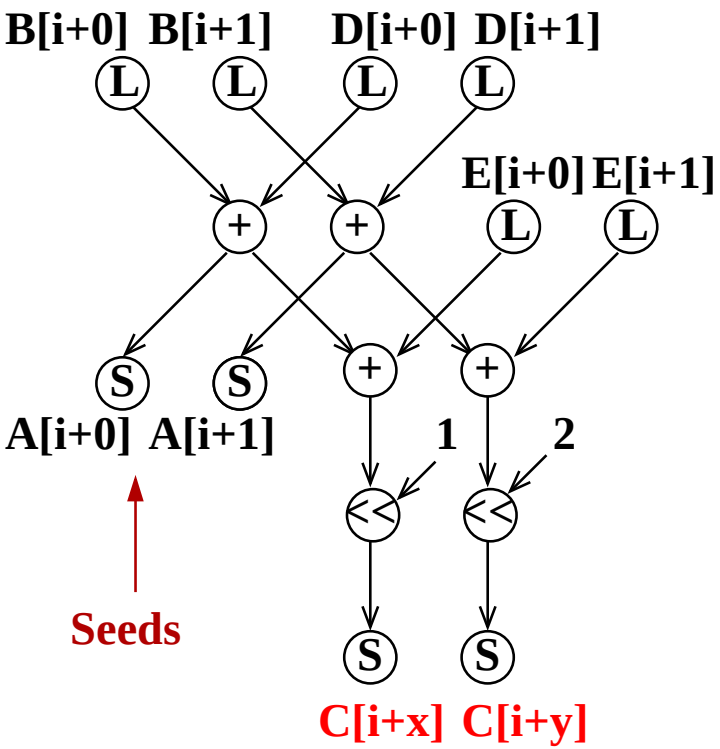

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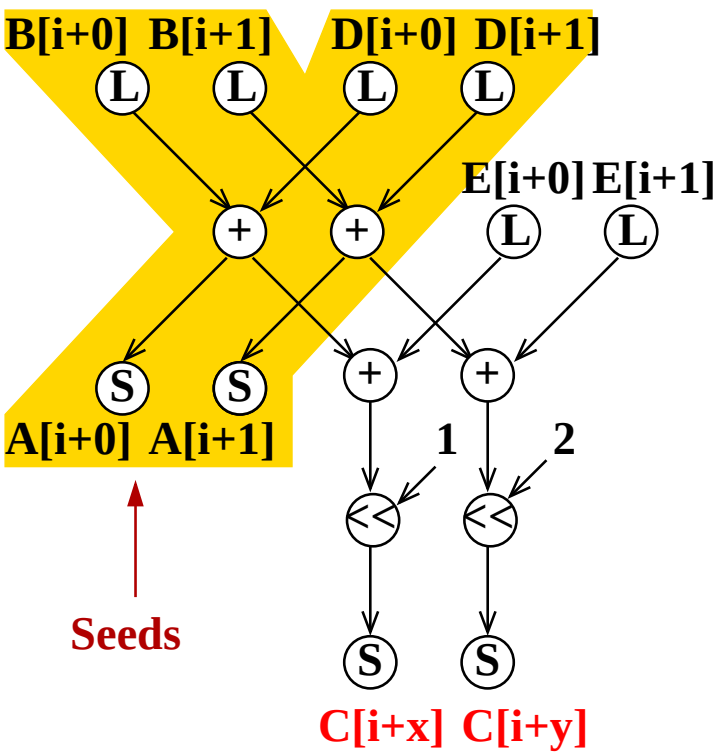

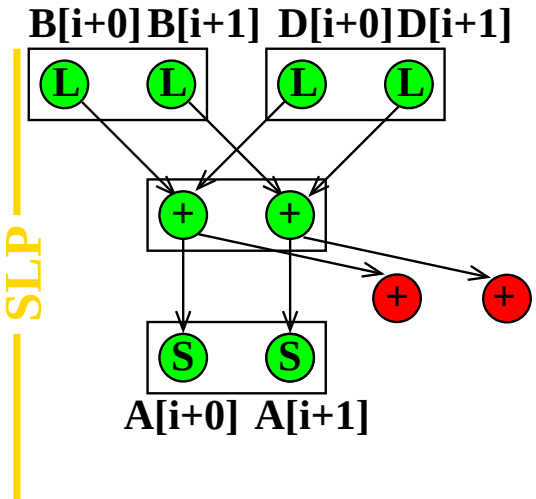

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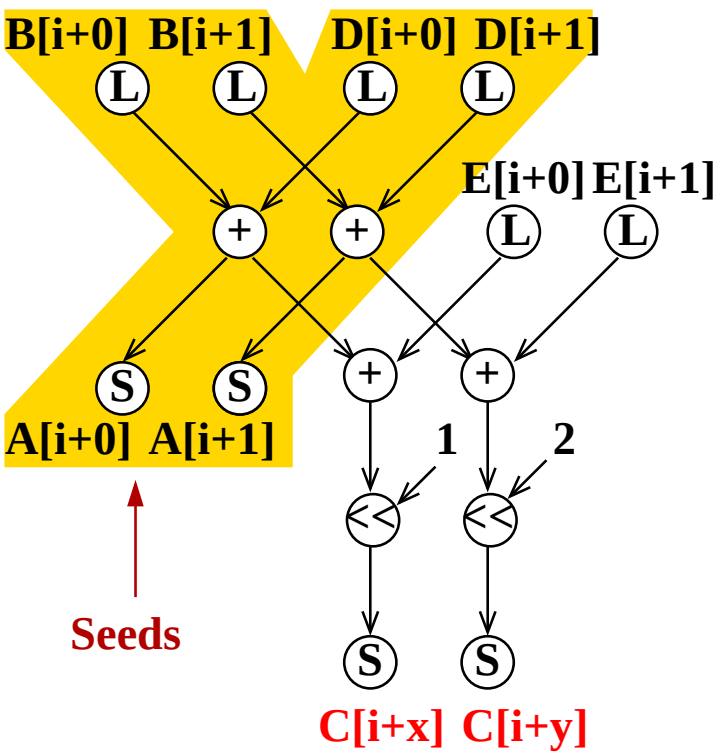

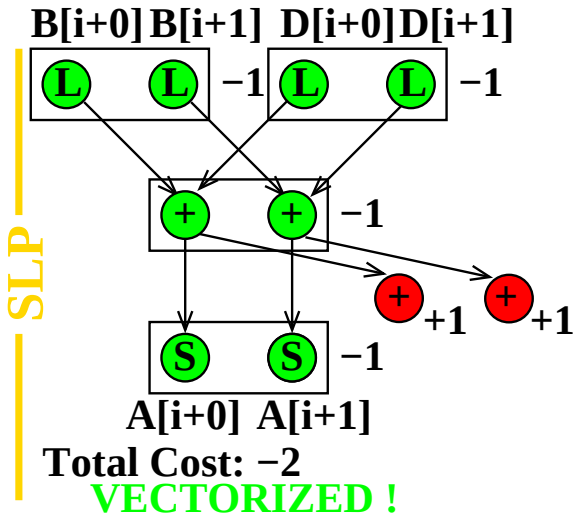

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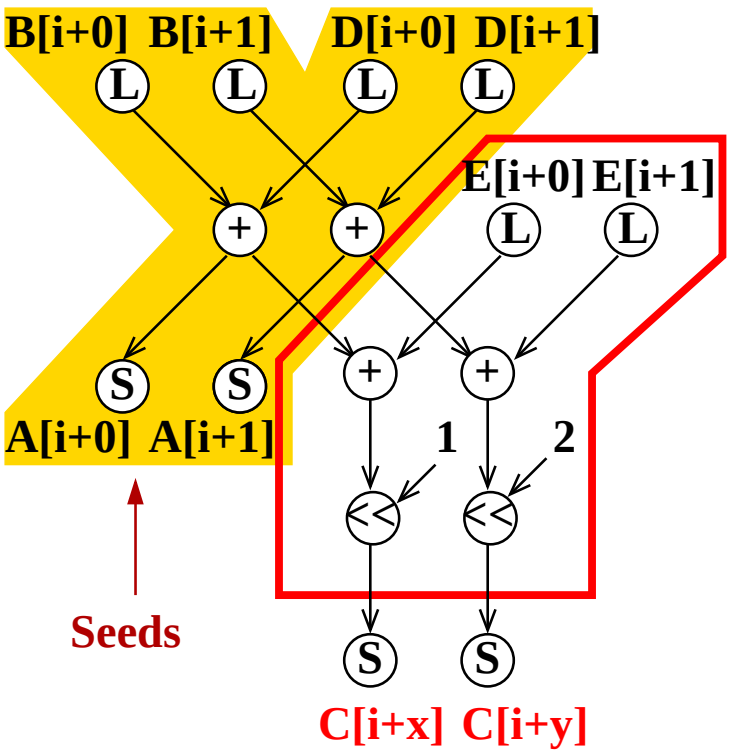

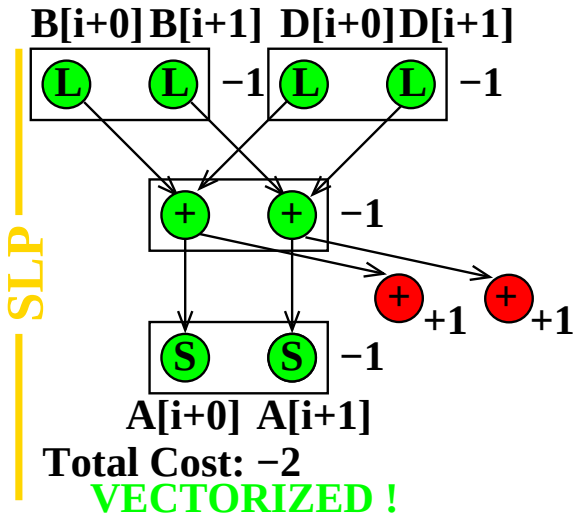

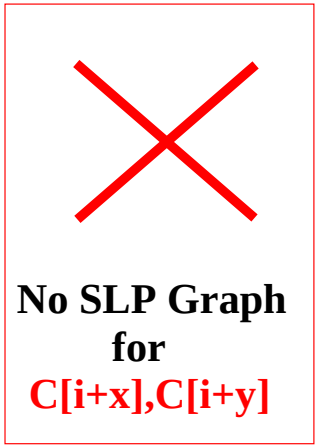

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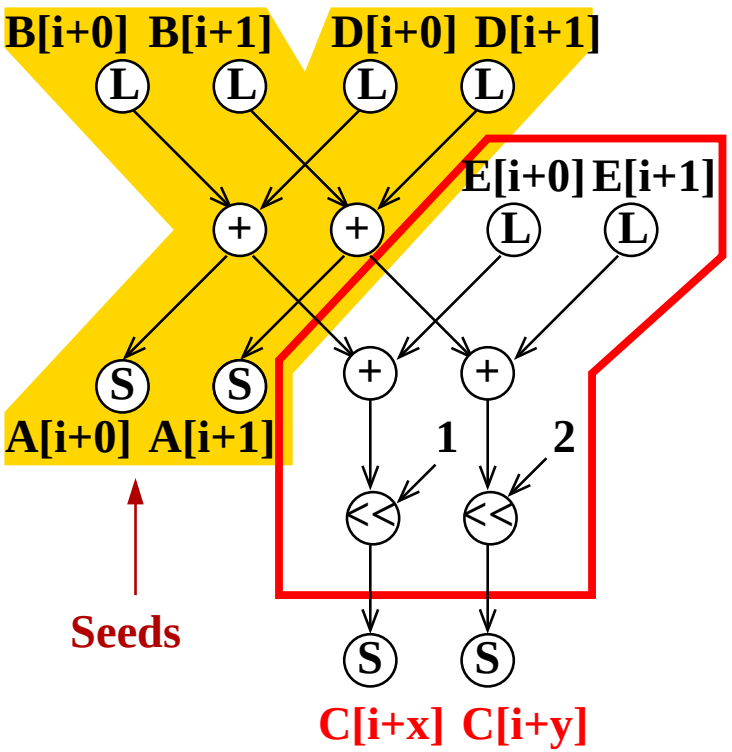

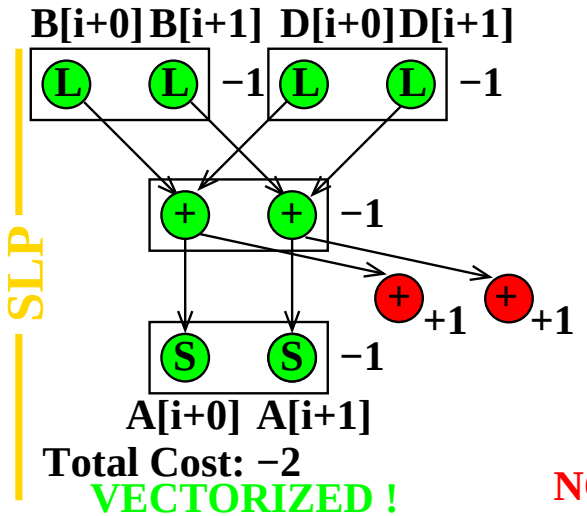

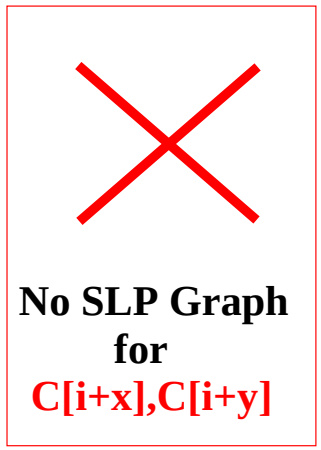

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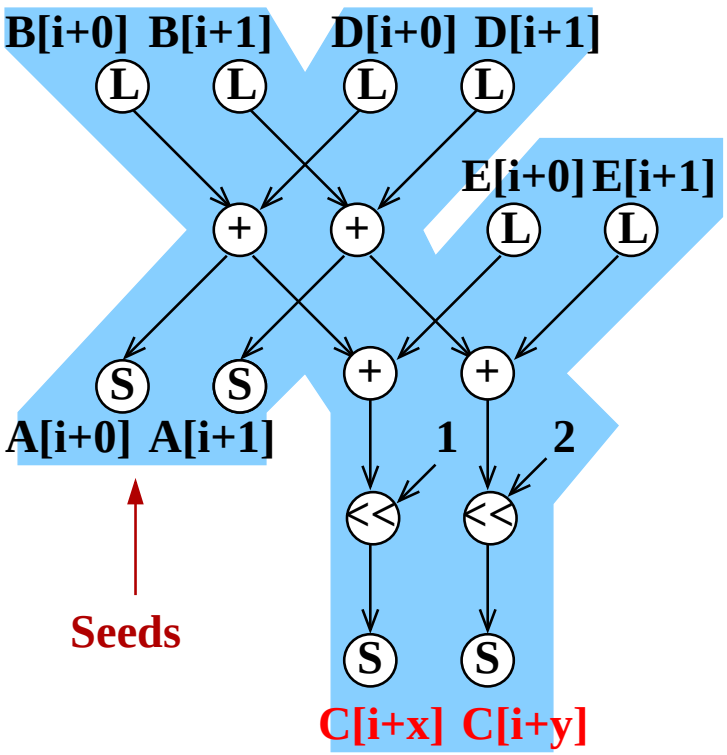
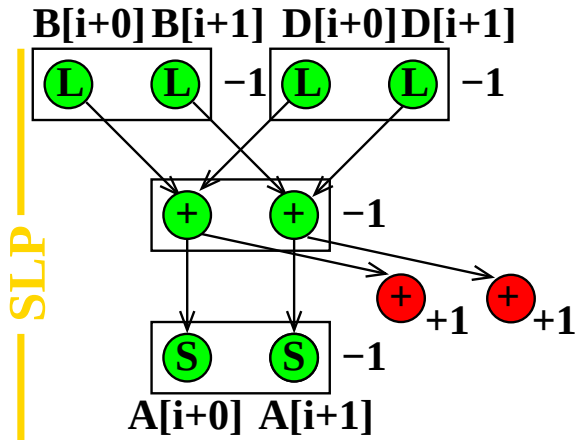
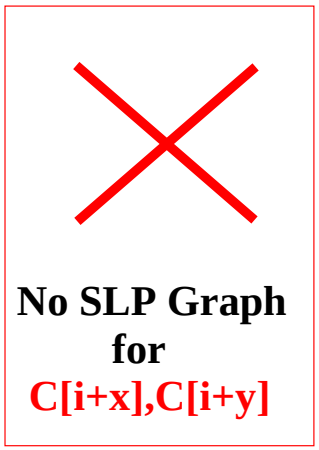
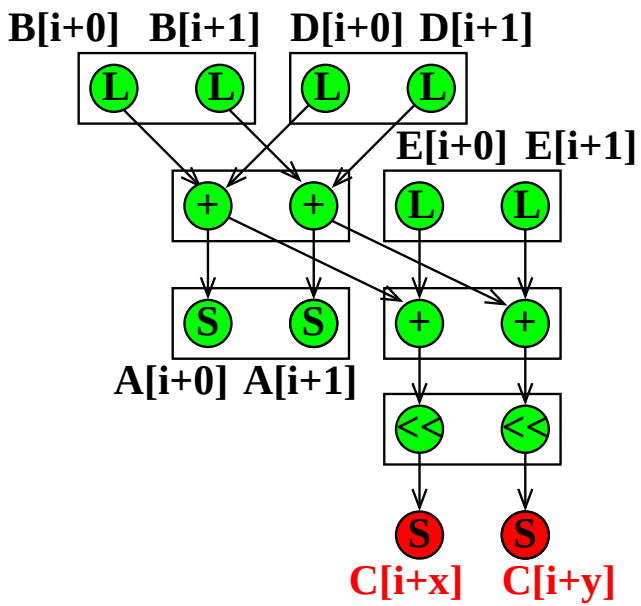


SLP



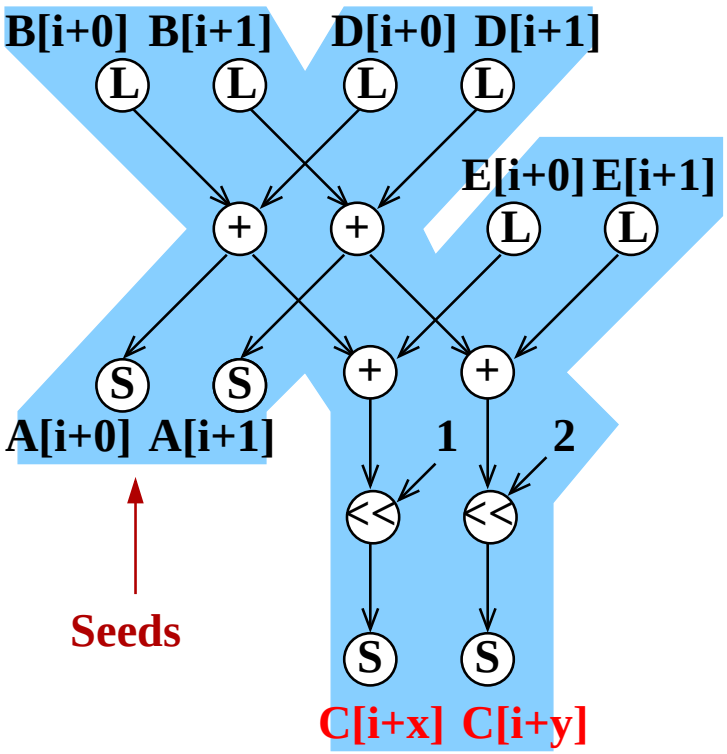


SG−SLP

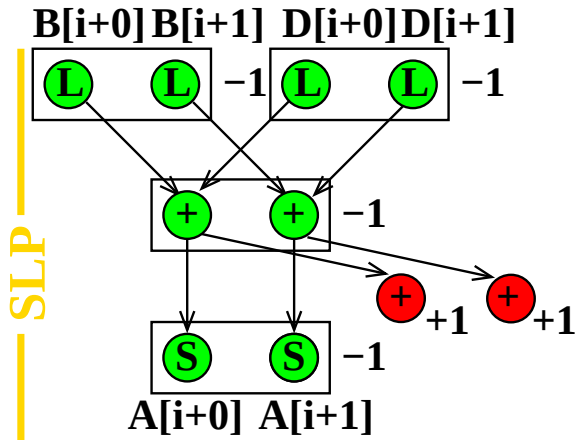


2. SLP Fails due to Unreachable Instructions

```
long tmp1, tmp2, A[], B[], C[], D[], E[];
tmp1 = B[i+0] + D[i+0];
tmp2 = B[i+1] + D[i+1];
A[i+0] = tmp1;
A[i+1] = tmp2;
C[i+x] = (tmp1 + E[i+0]) << 1;
C[i+y] = (tmp2 + E[i+1]) << 2;
```

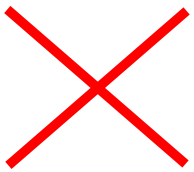


SLP



Total Cost: −2

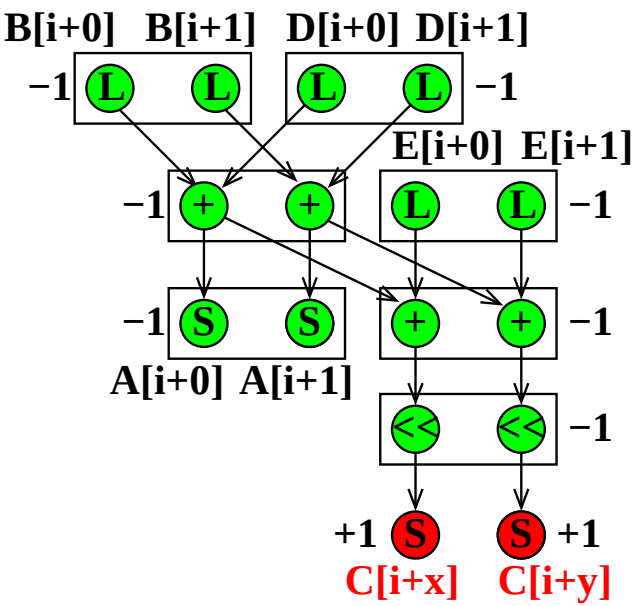
VECTORIZED !



No SLP Graph for C[i+x],C[i+y]

NOT VECTORIZED

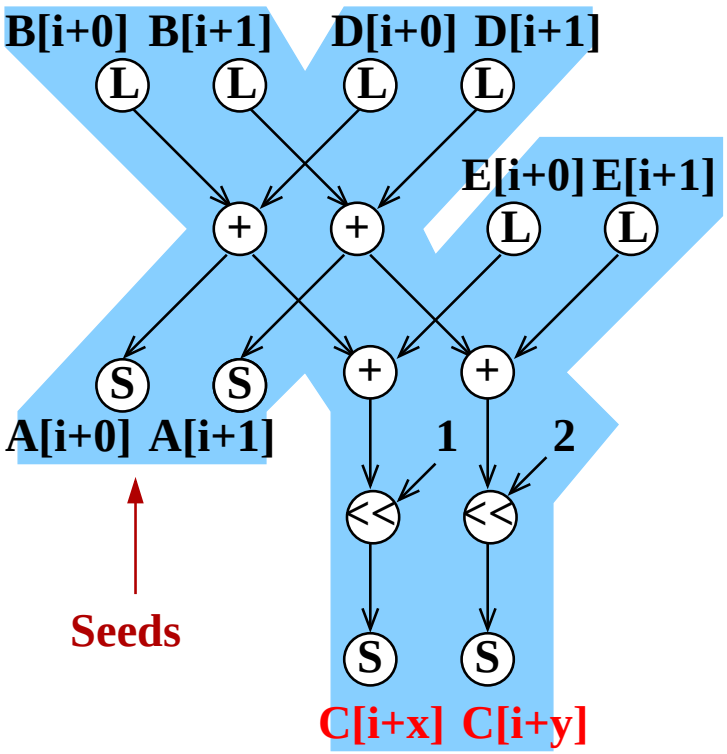
SG−SLP



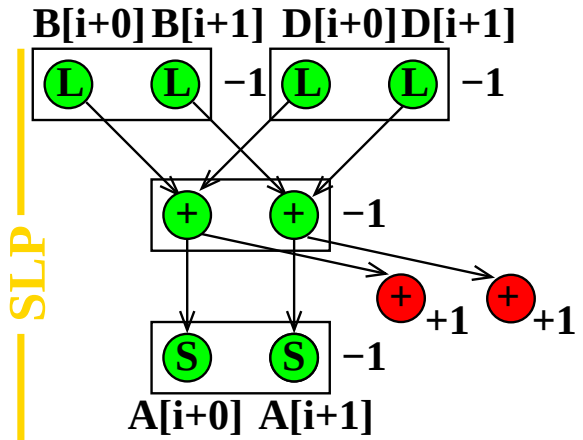
Total Cost: −5 VECTORIZED !

2. SLP Fails due to Unreachable Instructions

```
long tmp1, tmp2, A[], B[], C[], D[], E[];
tmp1 = B[i+0] + D[i+0];
tmp2 = B[i+1] + D[i+1];
A[i+0] = tmp1;
A[i+1] = tmp2;
C[i+x] = (tmp1 + E[i+0]) << 1;
C[i+y] = (tmp2 + E[i+1]) << 2;
```

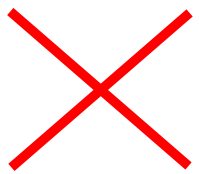


SLP



Total Cost: −2

VECTORIZED !



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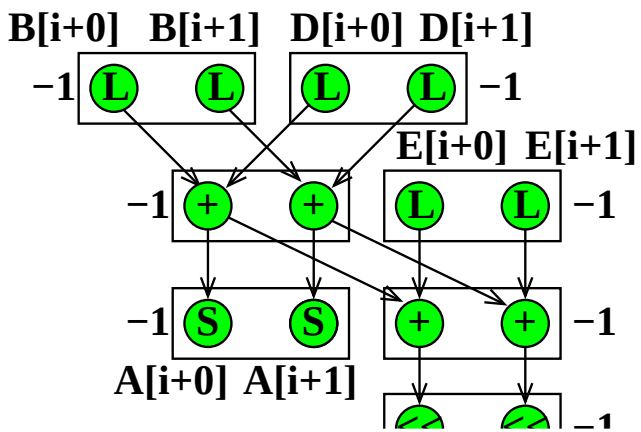
SG−SLP

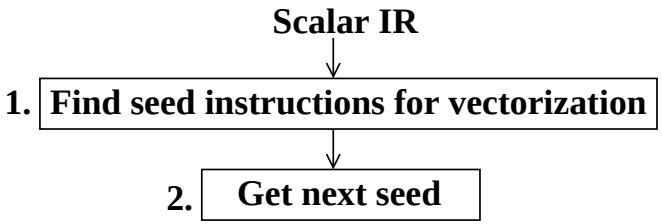


BETTER PERFORMANCE!

C[i+x] C[i+y]

Total Cost: −5 VECTORIZED !

SG-SLP Algorithm



- Seed instructions are:
  1. Consecutive Stores
  2. Reductions

SG-SLP Algorithm

- Seed instructions are:
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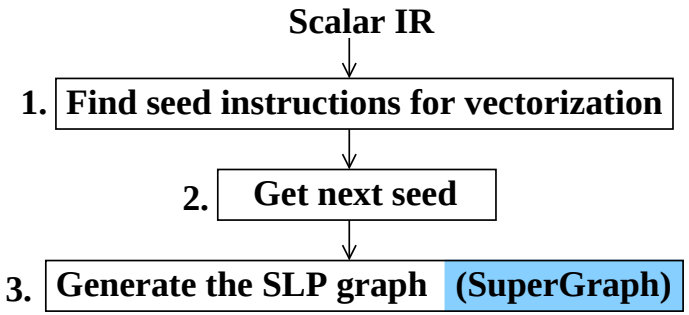
- Graph contains groups of vectorizable instructions



SG-SLP Algorithm

- Seed instructions are:
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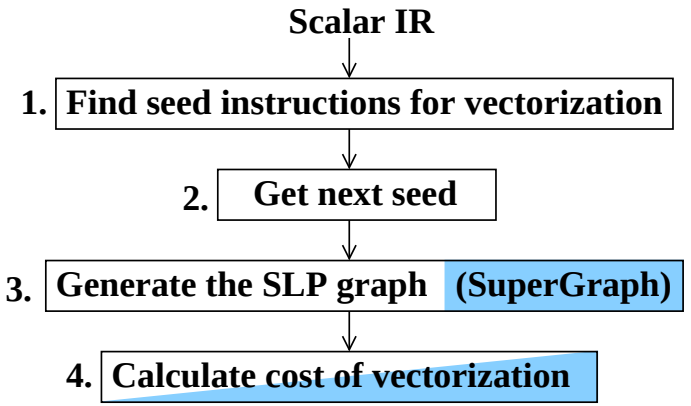
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count



SG-SLP Algorithm

- Seed instructions are:
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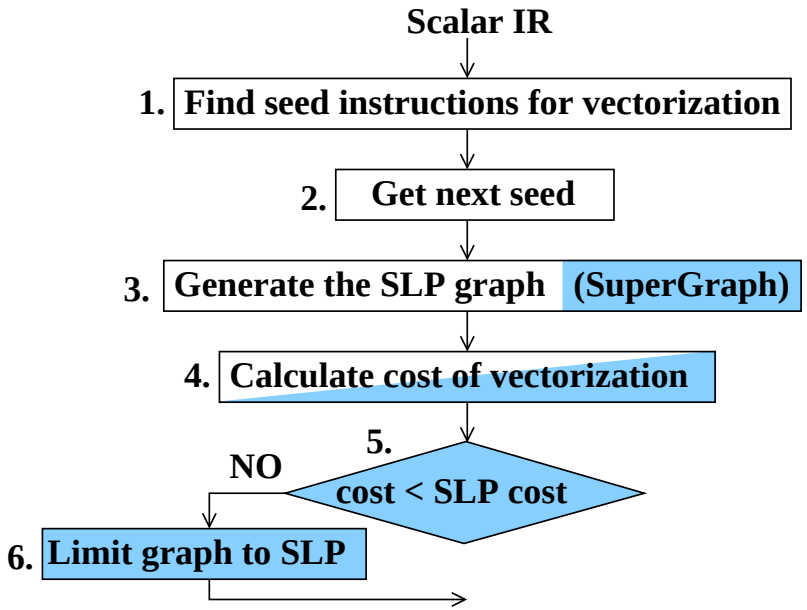
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count
- Check SG-SLP vs SLP profitability



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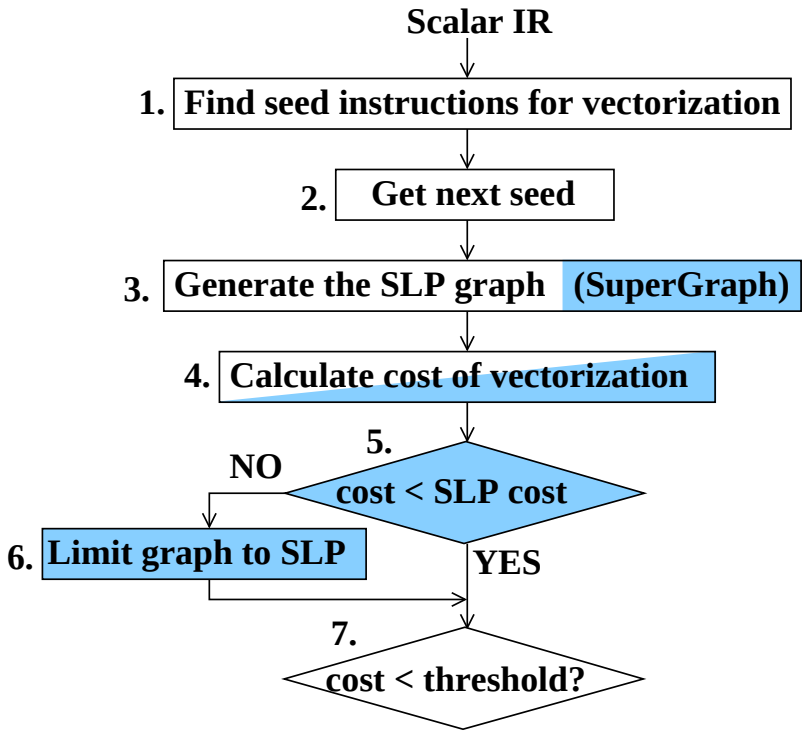

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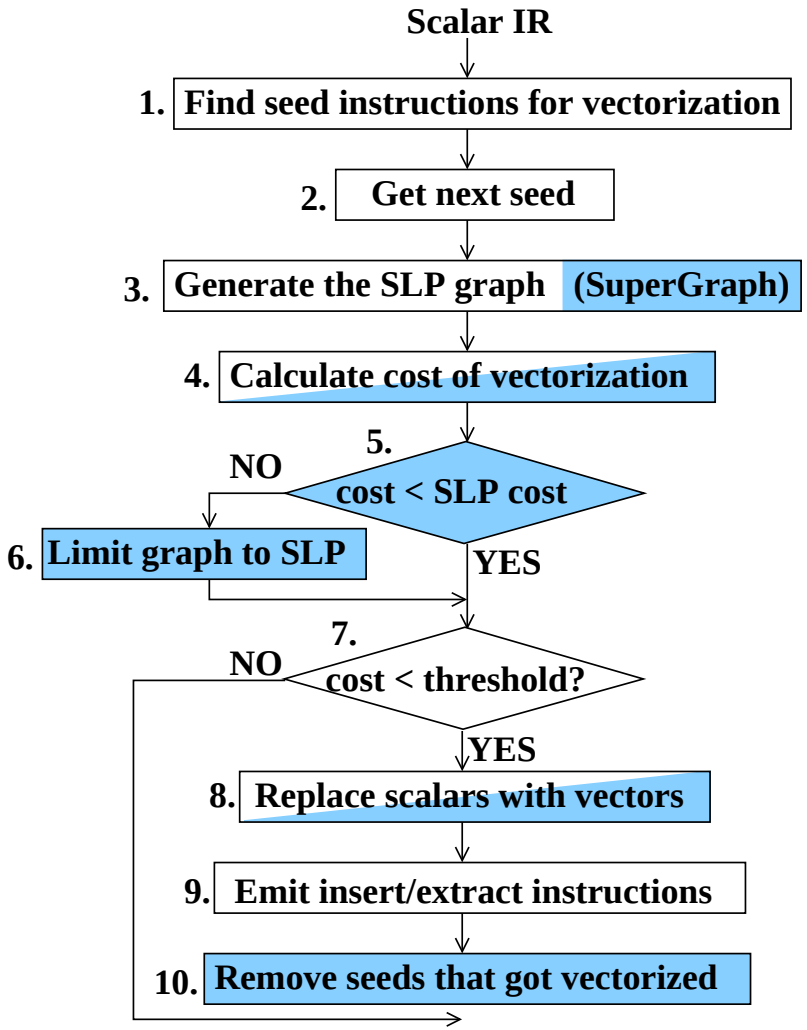
- Check SG-SLP vs SLP profitability
- Check overall profitability
- Generate vector code



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- Graph contains groups of vectorizable instructions
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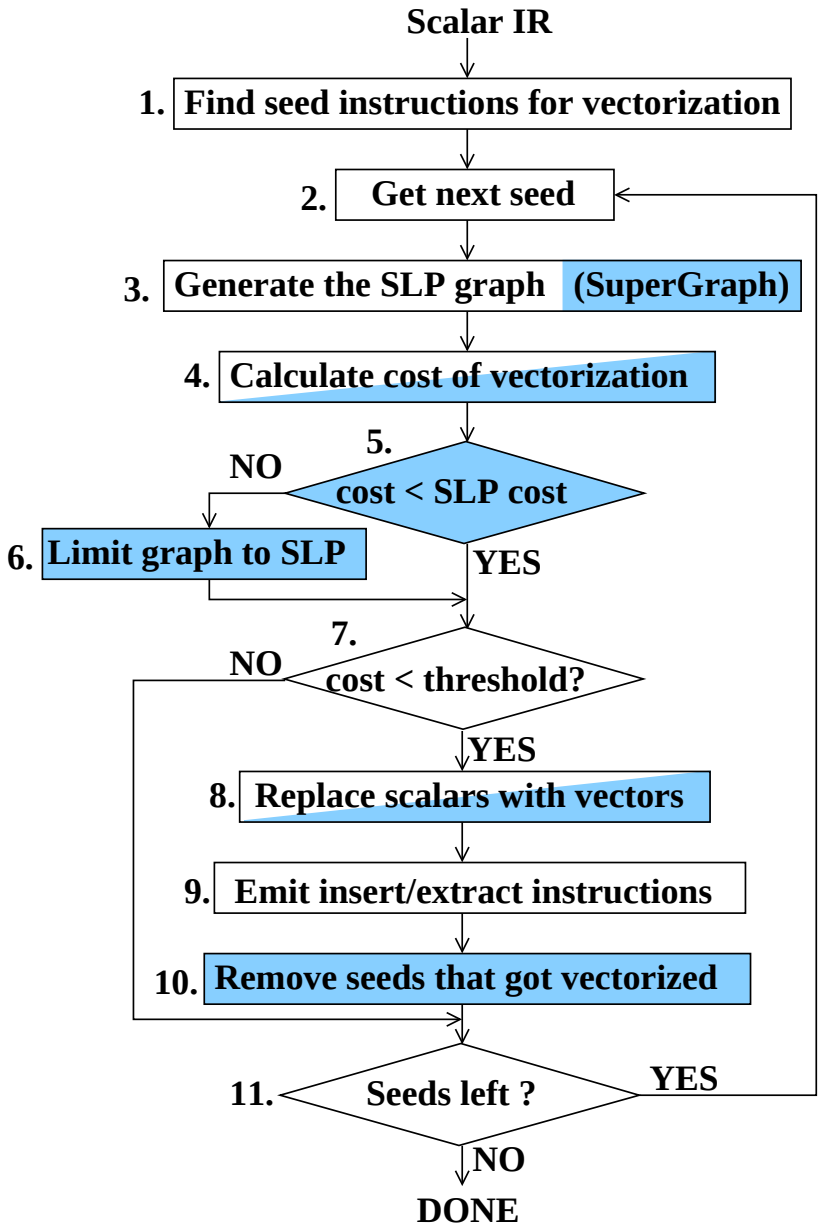
- Check SG-SLP vs SLP profitability
- Check overall profitability
- Generate vector code
- Repeat



Experimental Setup

- Implemented SG-SLP in LLVM 3.6

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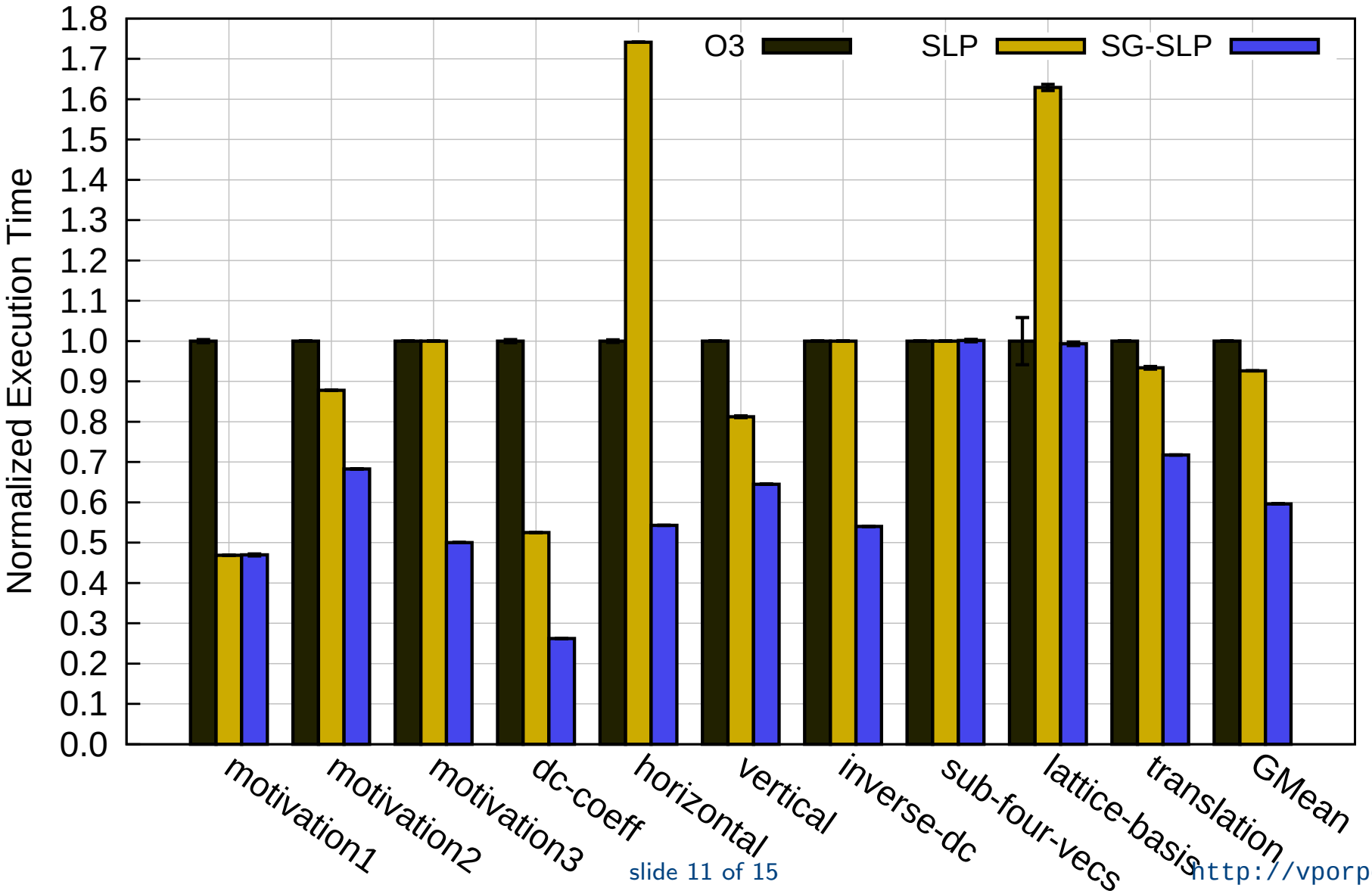
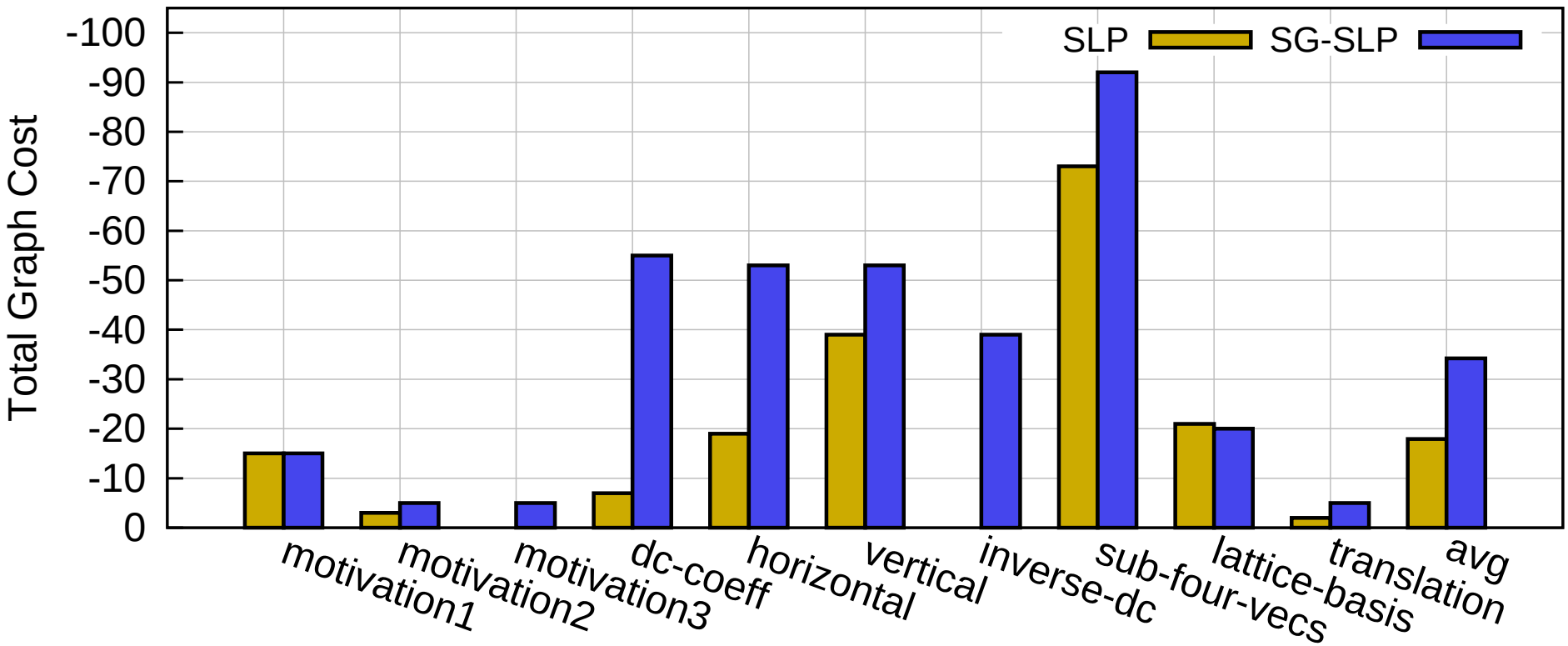
  3. O3 + SG-SLP enabled (SG-SLP)

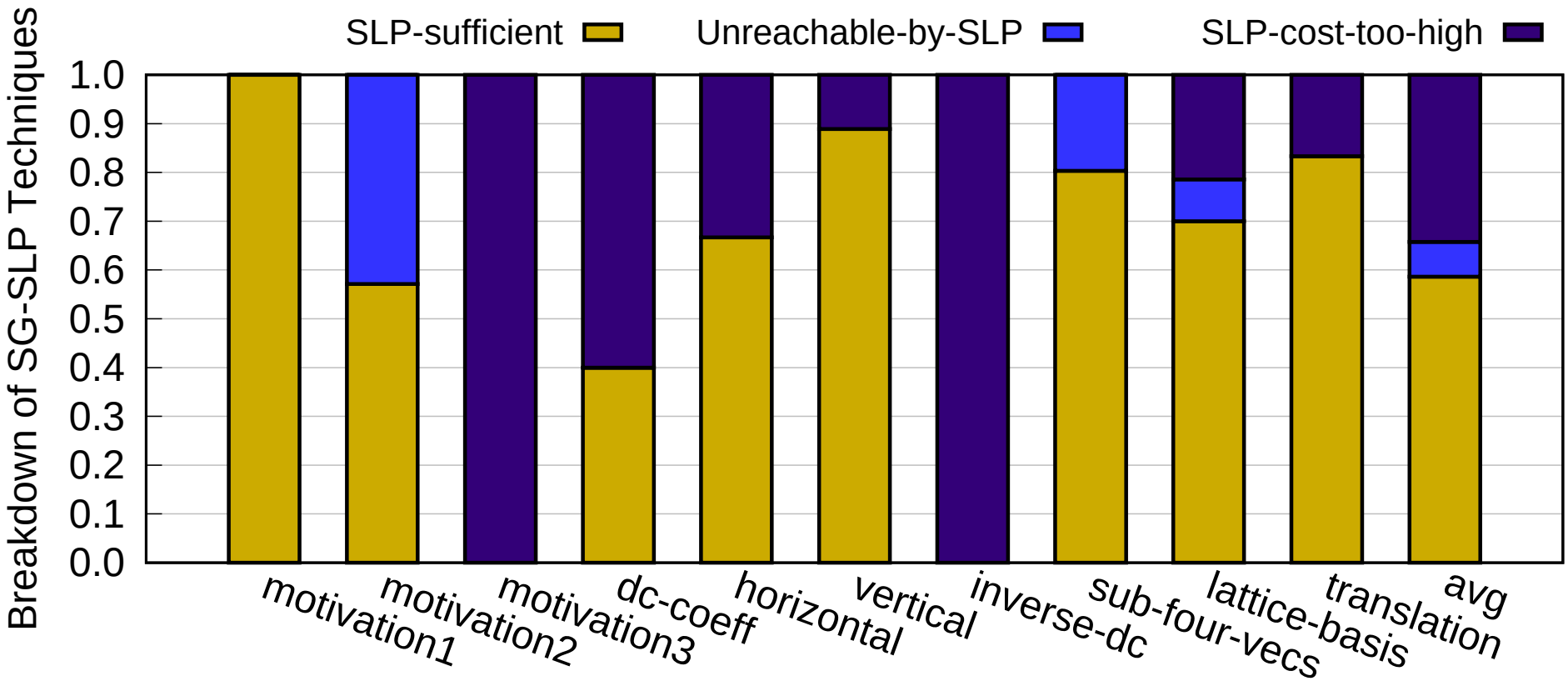
Performance (normalized to O3)



Static Cost (the higher the better)

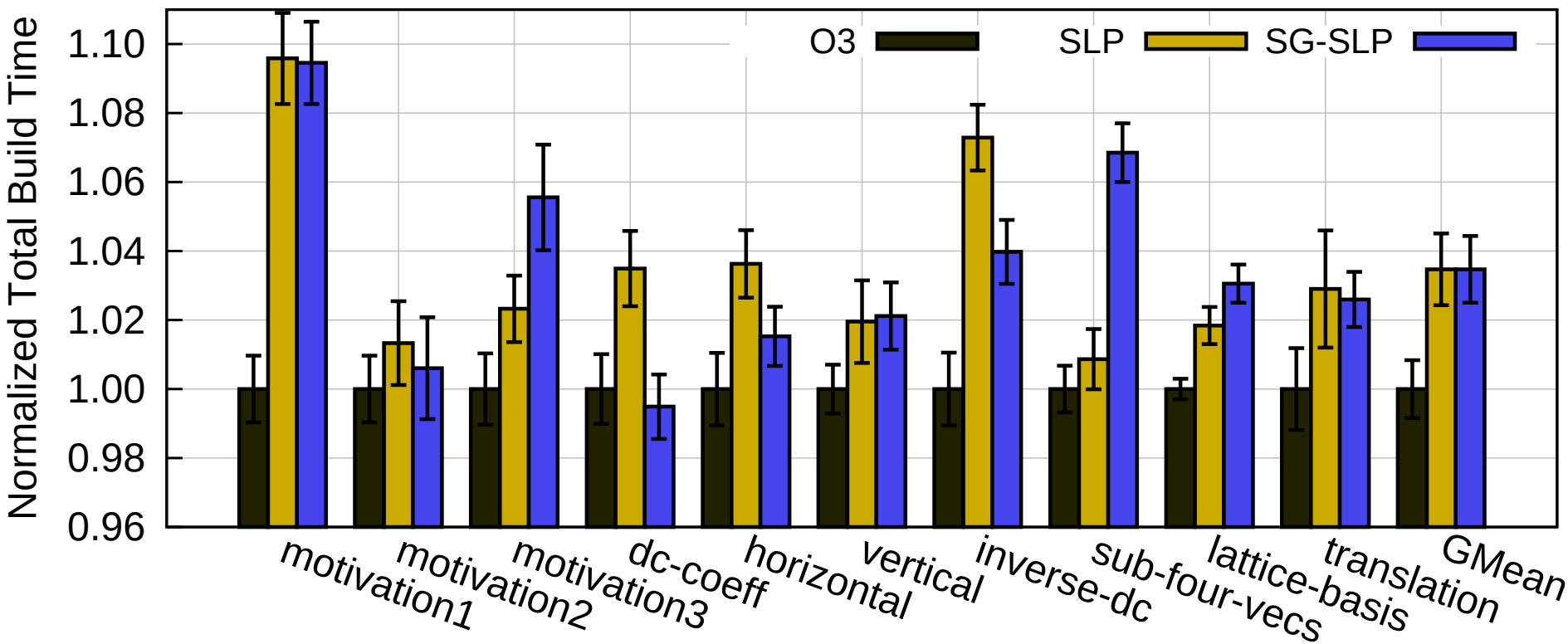


Breakdown of SG-SLP Improvements



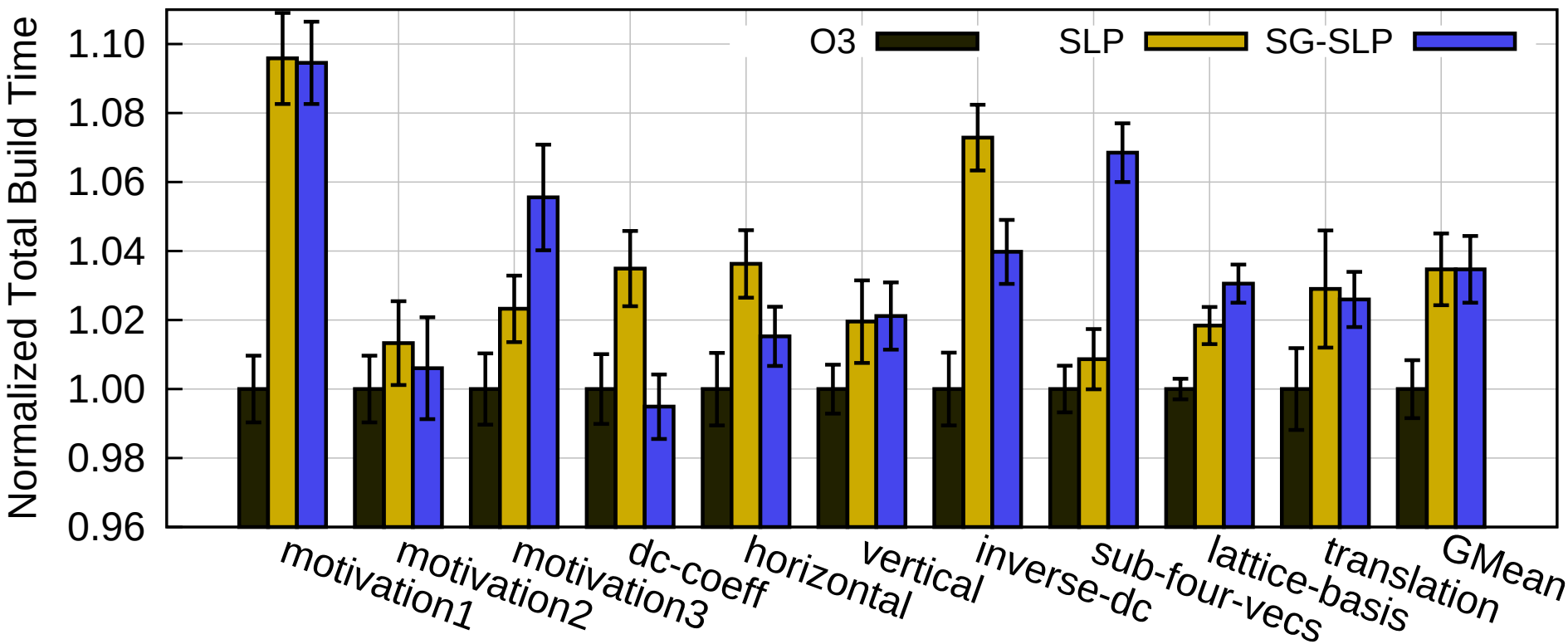
Total Compilation Time

- No significant difference in compilation time



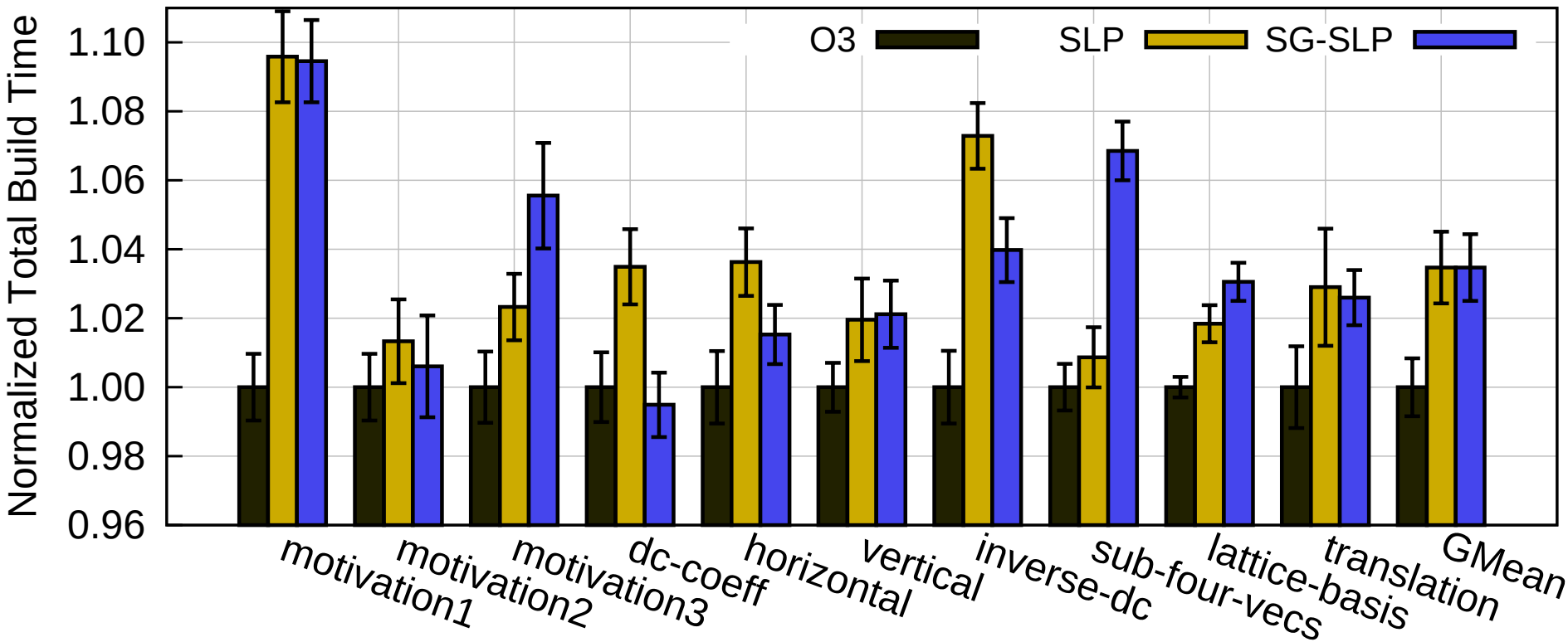
Total Compilation Time

- No significant difference in compilation time
- SG-SLP fails early on non-vectorizable code



Total Compilation Time

- No significant difference in compilation time
- SG-SLP fails early on non-vectorizable code
- Vectorized code usually decreases code size



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  - Unreachable Instructions by SLP
- Improves performance and vectorization coverage
- No significant impact on compilation time