Look-Ahead SLP: Auto-vectorization in the presence of commutative operations

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- Superword Level Parallelism [Larsen PLDI'00]

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  - Usually run SLP after the Loop Vectorizer

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- Operands can be reordered
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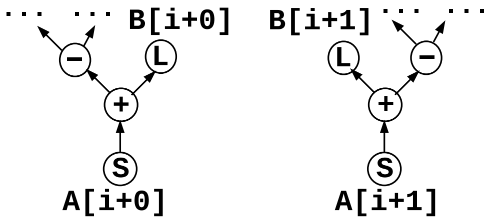

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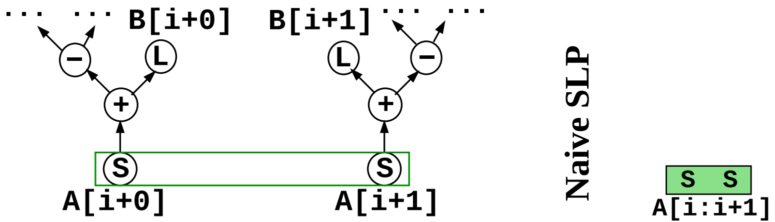

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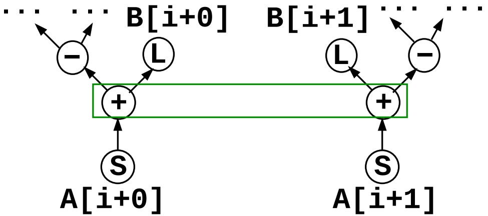
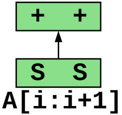


Naive SLP



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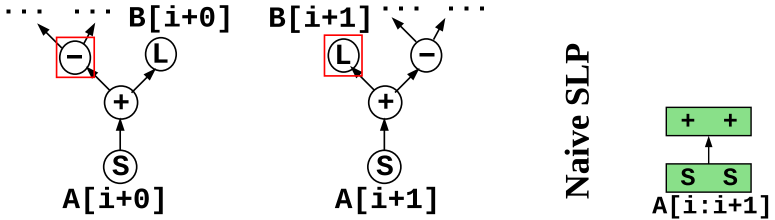

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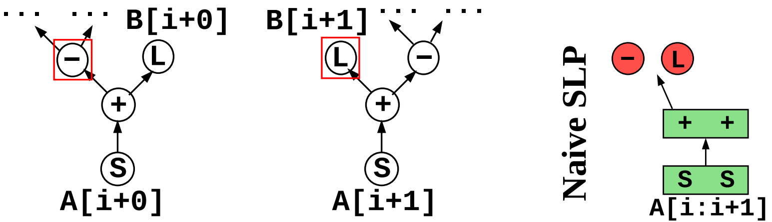

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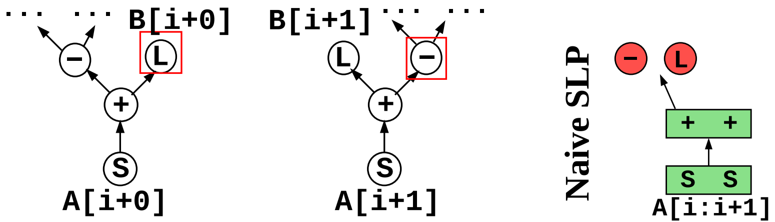

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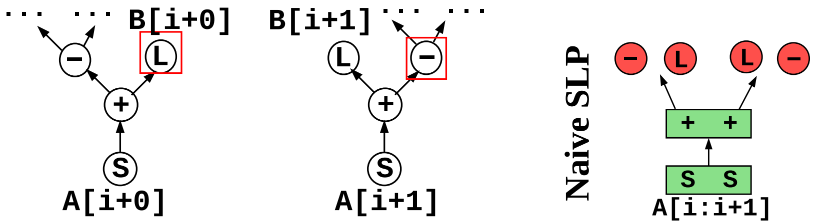

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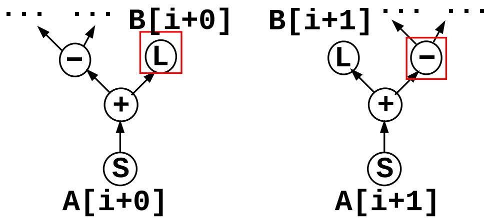
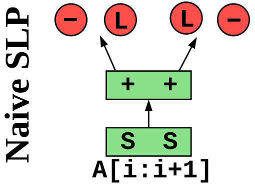


Vectorization would STOP without reordering!



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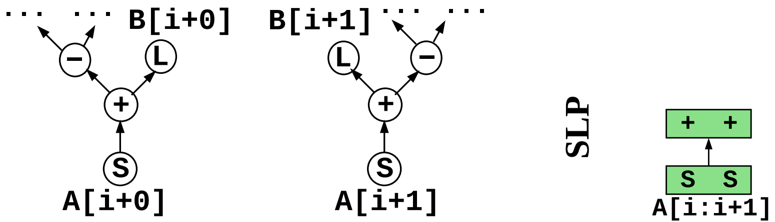

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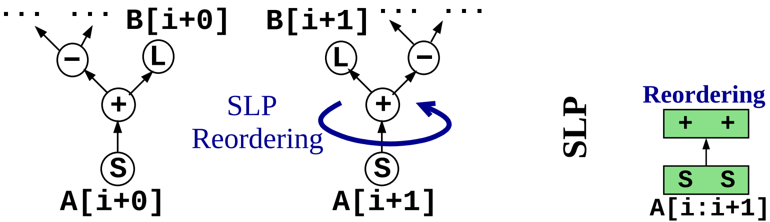

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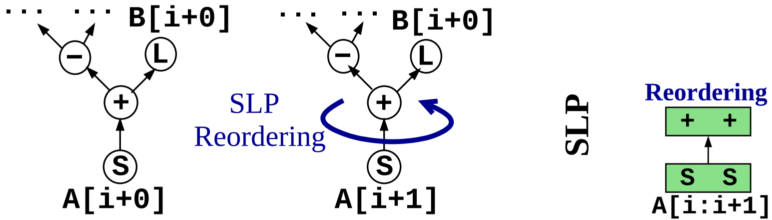

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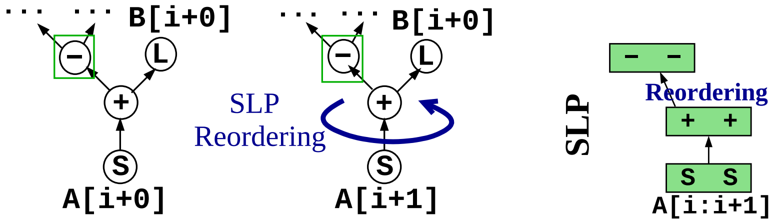

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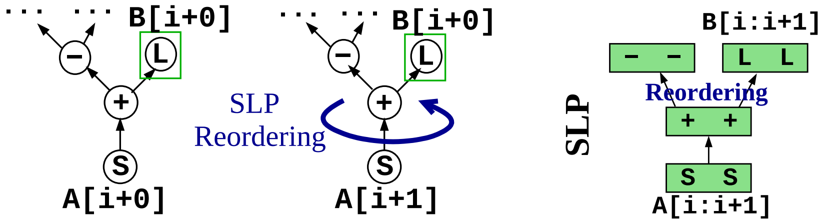

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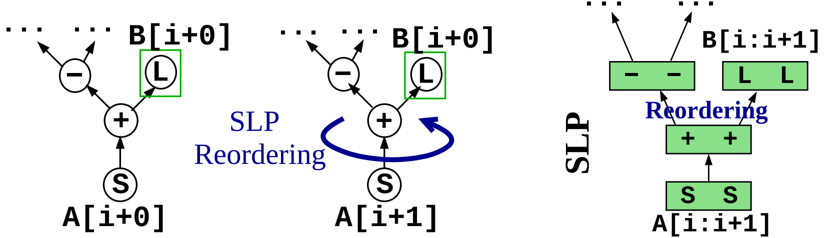

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  1. Load address mismatch further up the graph
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  3. Reodering across chains of commutative operations
- Look-Ahead SLP (LSLP) provides a solution to all three.

1/3 Load address mismatch

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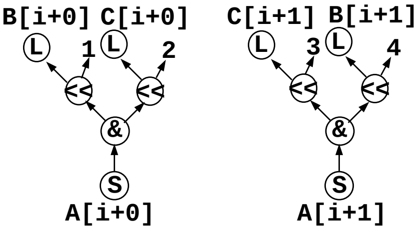

Lane 1 Lane 2

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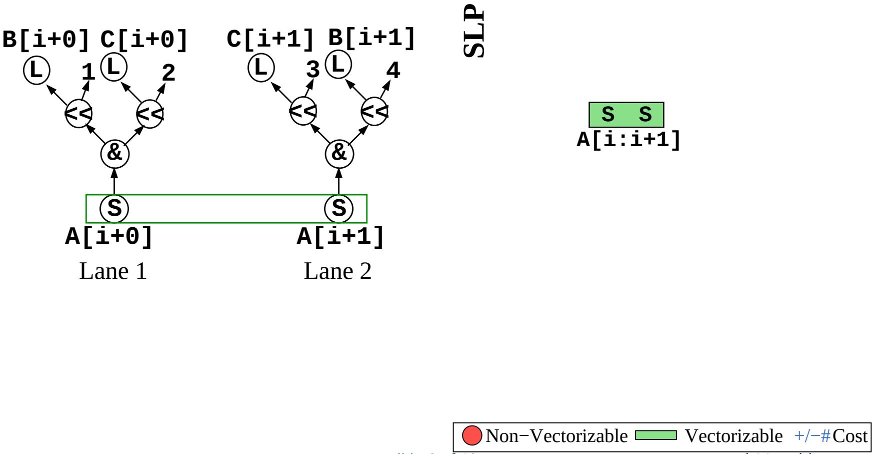

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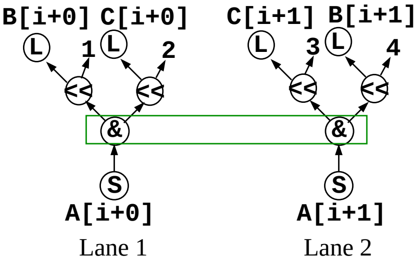
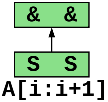


SLP



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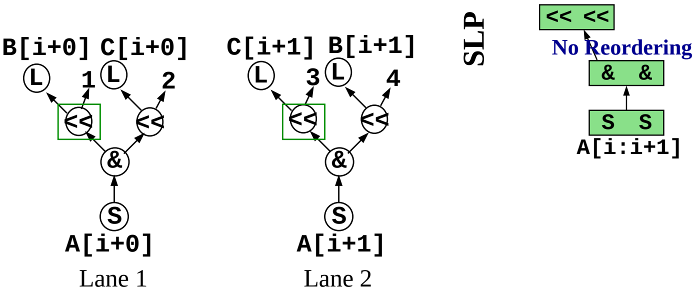

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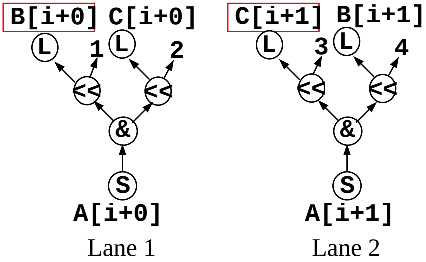

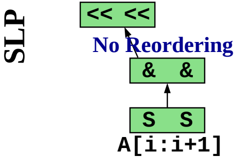

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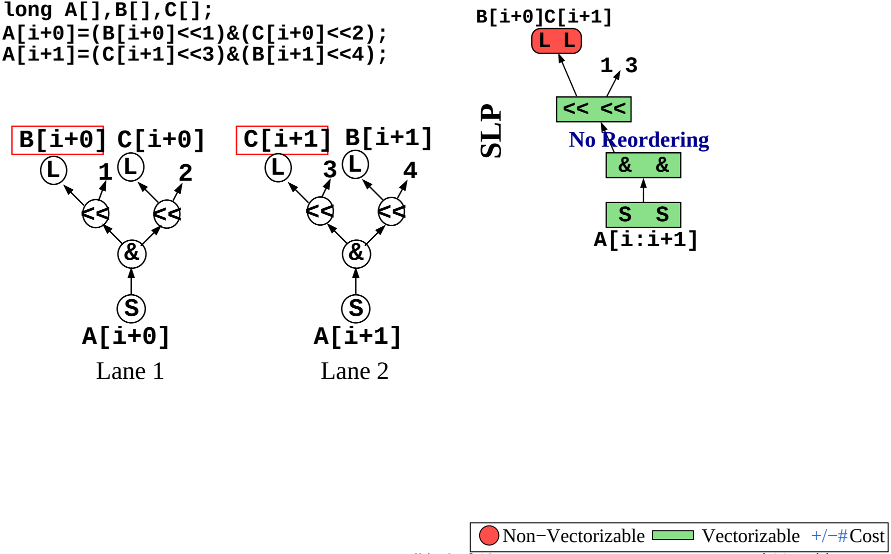

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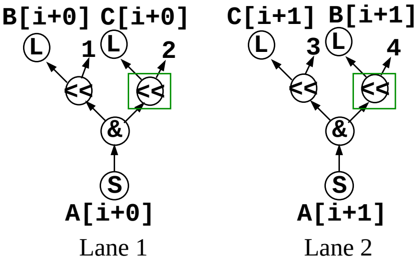

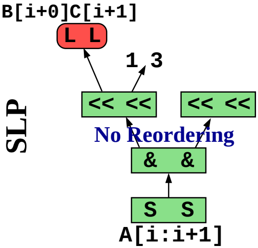

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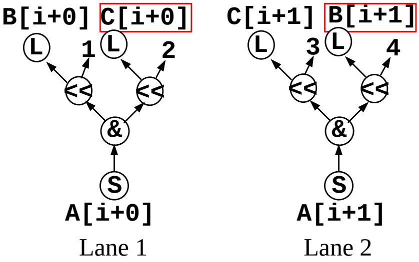

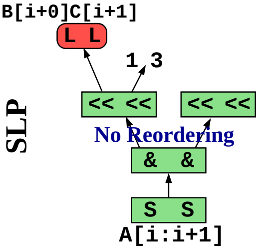

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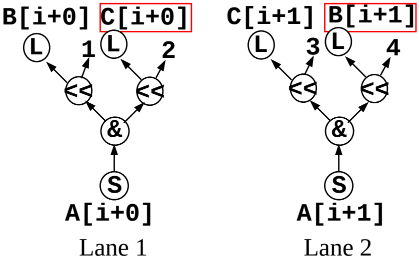

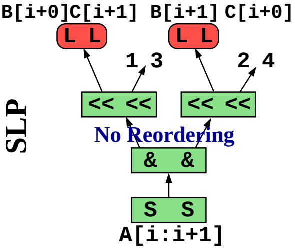

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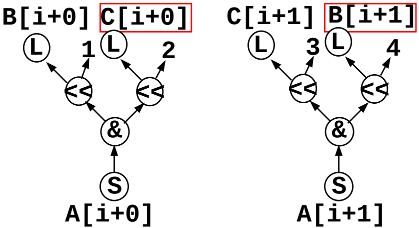
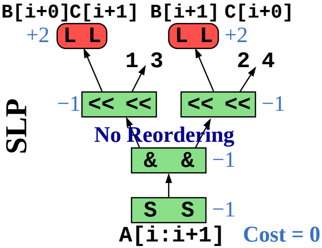


Lane 1 Lane 2



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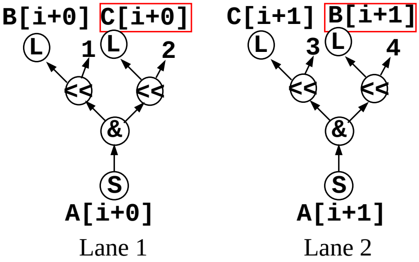

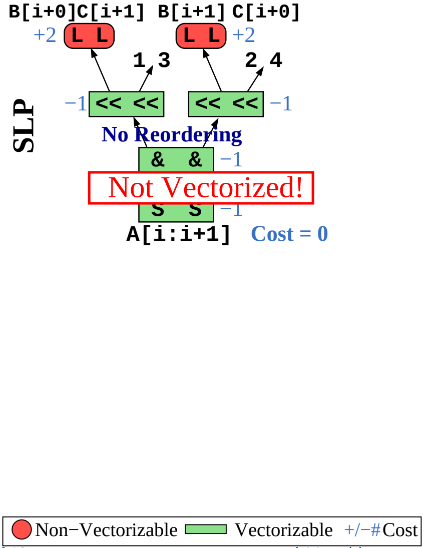

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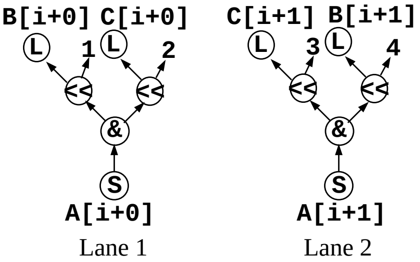

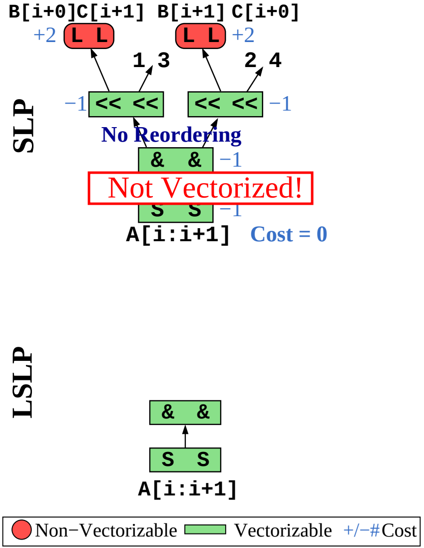

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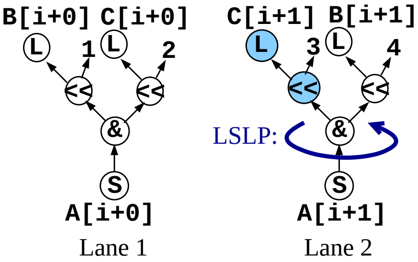
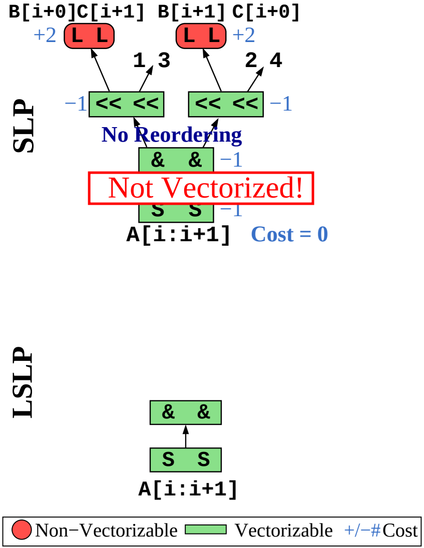
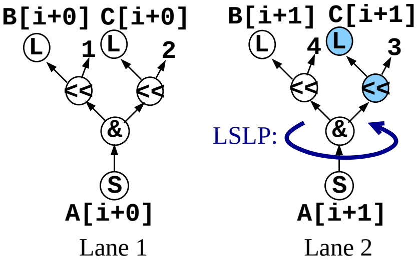
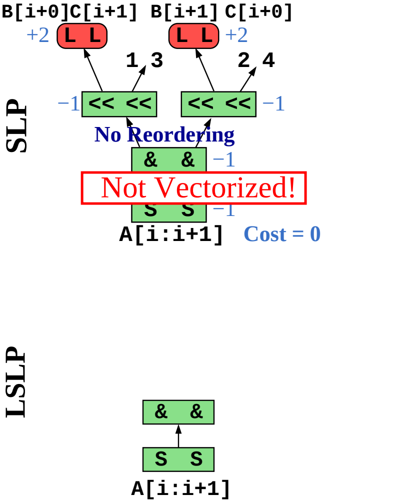




1/3 Load address mismatch

```
long A[],B[],C[];
A[i+0]=(B[i+0]<<1)&(C[i+0]<<2);
A[i+1]=(C[i+1]<<3)&(B[i+1]<<4);
```





1/3 Load address mismatch

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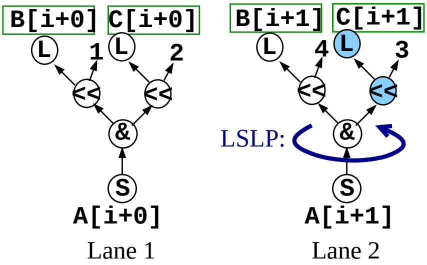
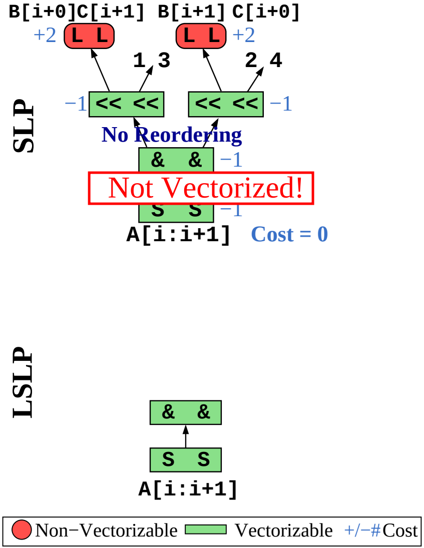
```





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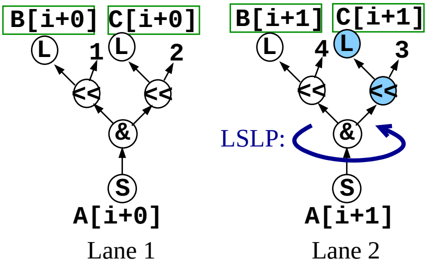

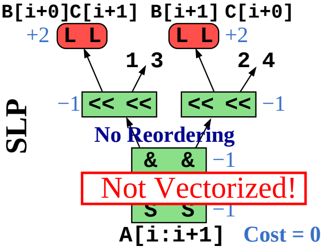

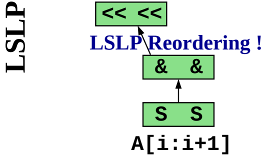

Non−Vectorizable Vectorizable +/−#Cost

1/3 Load address mismatch

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```

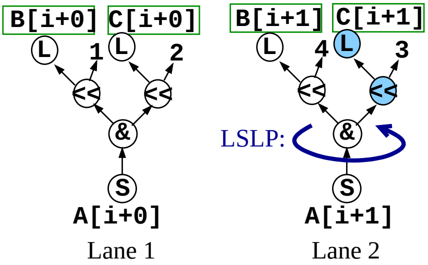

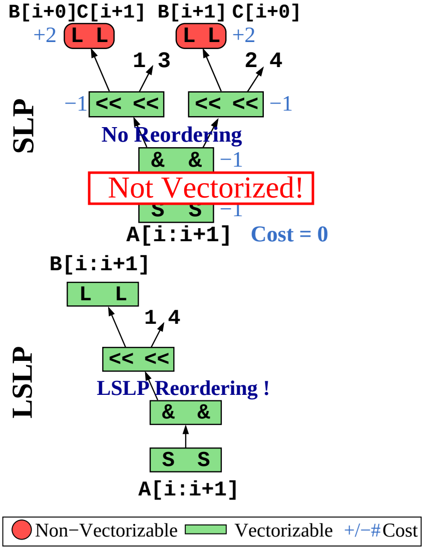

 http://vporpo.me

1/3 Load address mismatch

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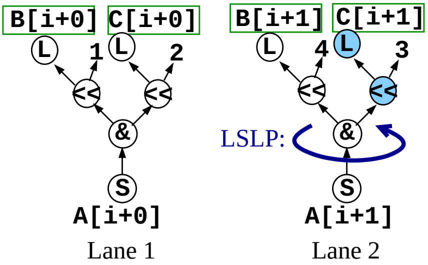
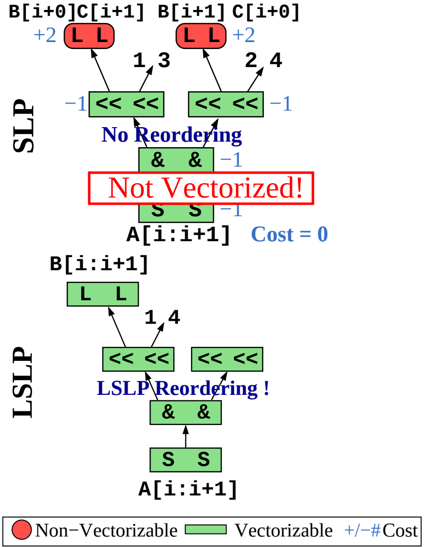
```





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A[i+1]=(C[i+1]<<3)&(B[i+1]<<4);
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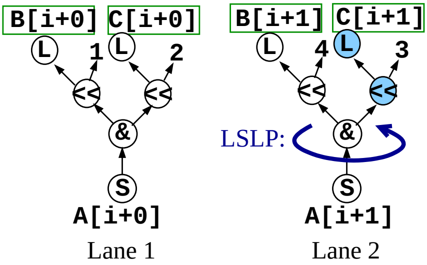

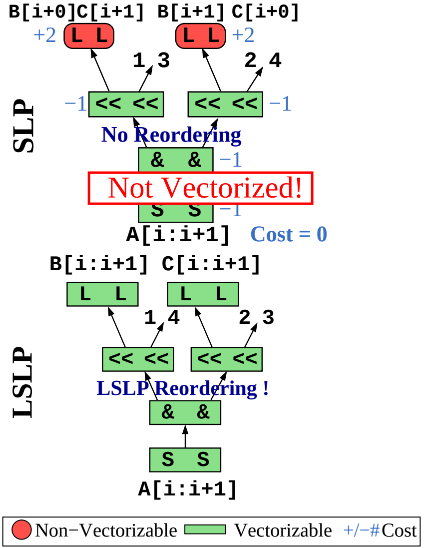

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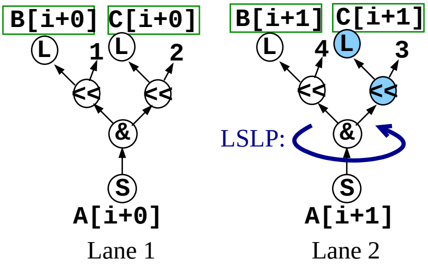

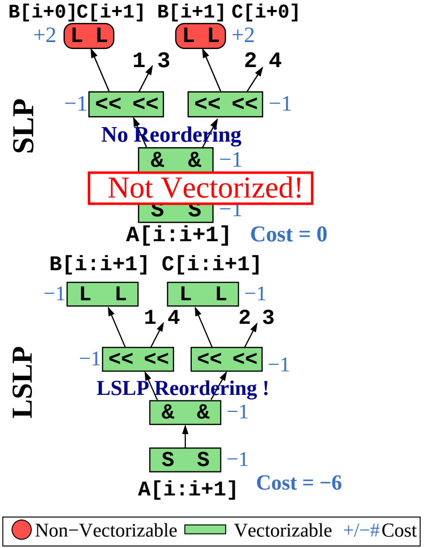

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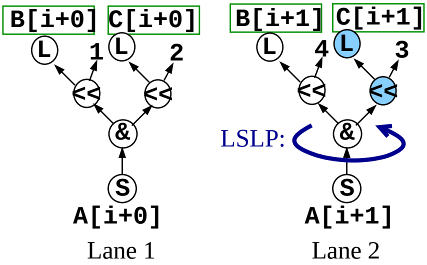
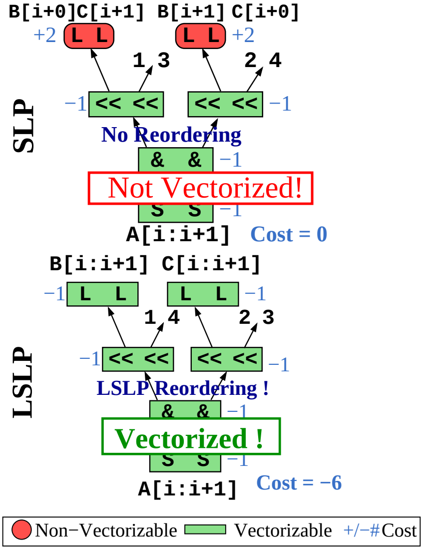


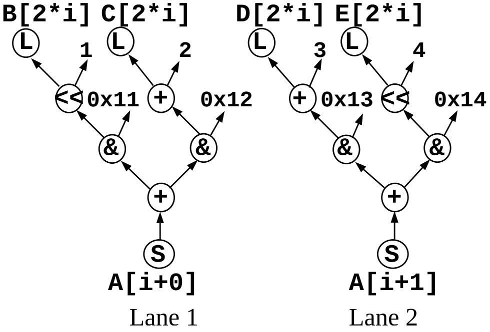


2/3 Opcodes mismatch

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

2/3 Opcodes mismatch

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```



2/3 Opcodes mismatch

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```
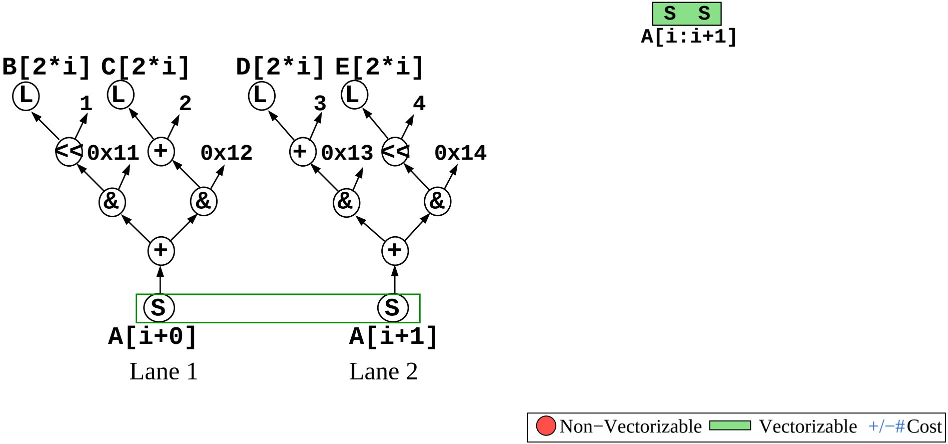

SLP



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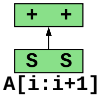
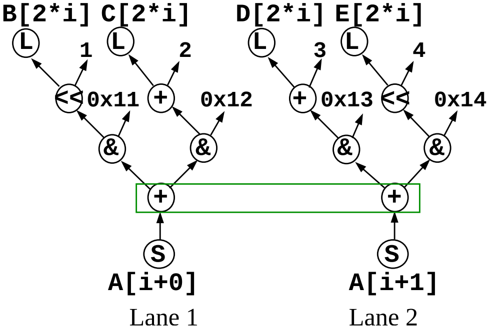
```

SLP





Non−Vectorizable Vectorizable +/−#Cost

2/3 Opcodes mismatch

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unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

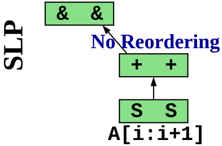

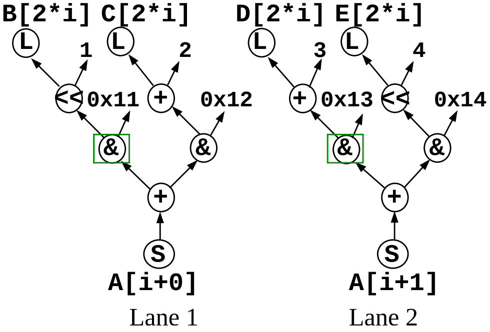

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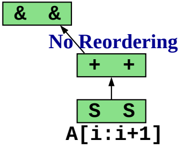
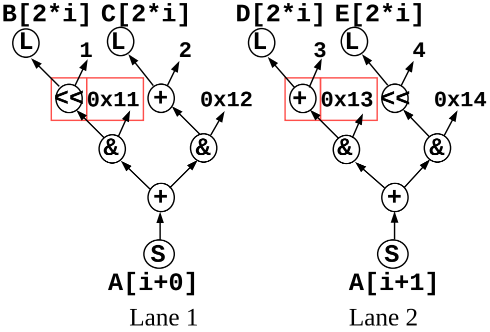
```

SLP





Non−Vectorizable Vectorizable +/−#Cost

2/3 Opcodes mismatch

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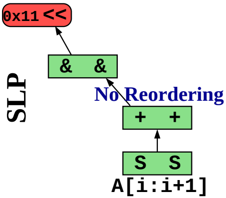

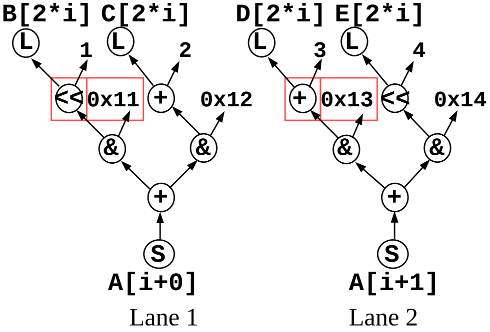

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```

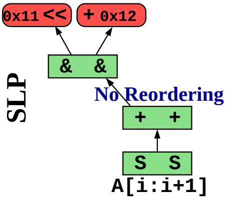

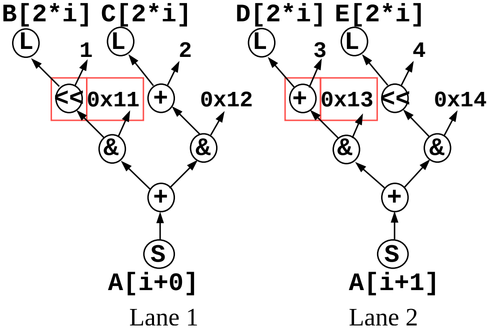

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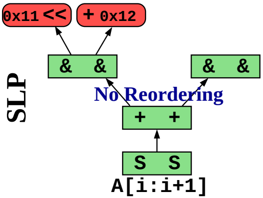
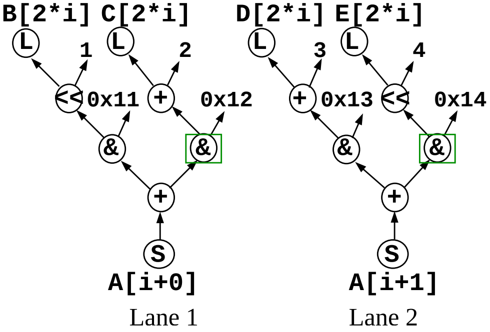
```





Non−Vectorizable Vectorizable +/−#Cost

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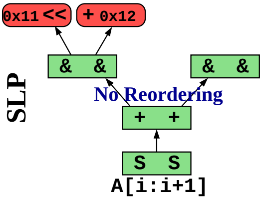

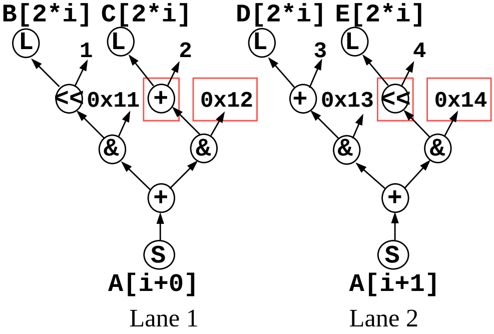

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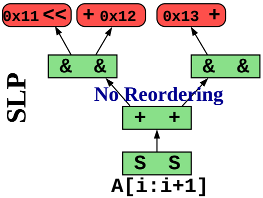

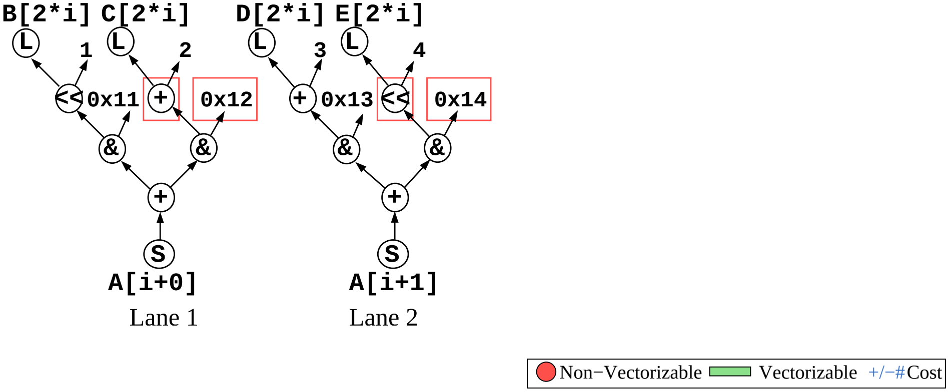

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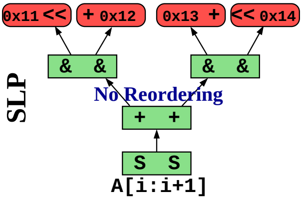

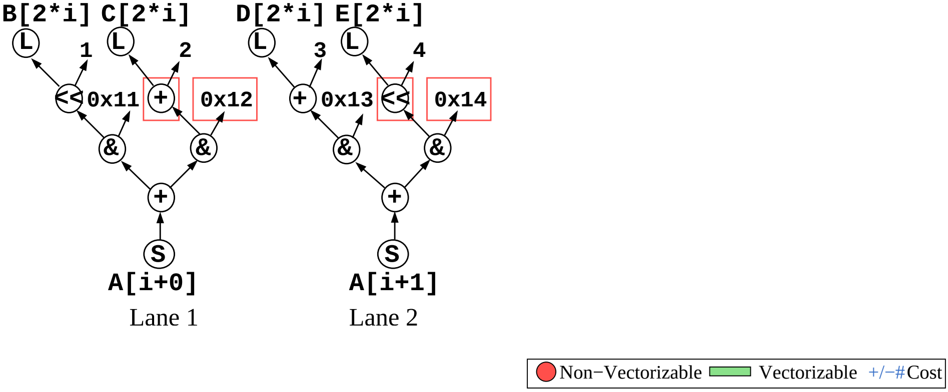

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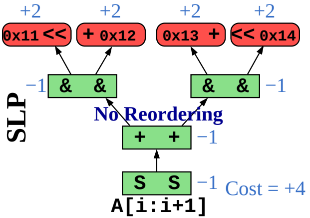

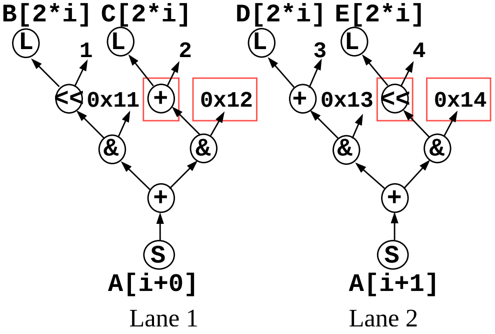

Non−Vectorizable Vectorizable +/−#Cost

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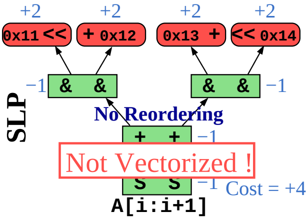

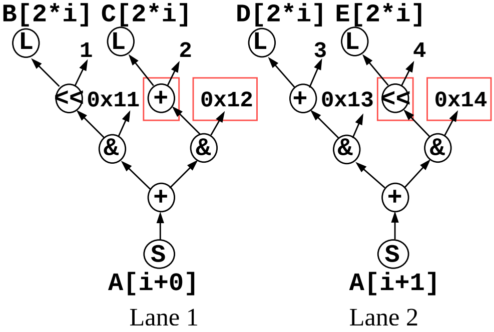

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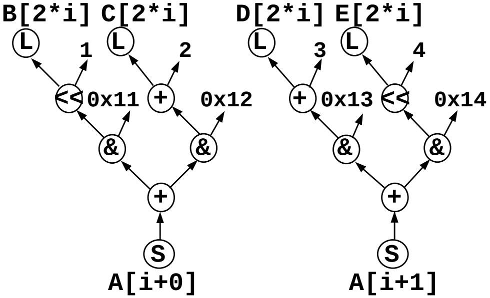
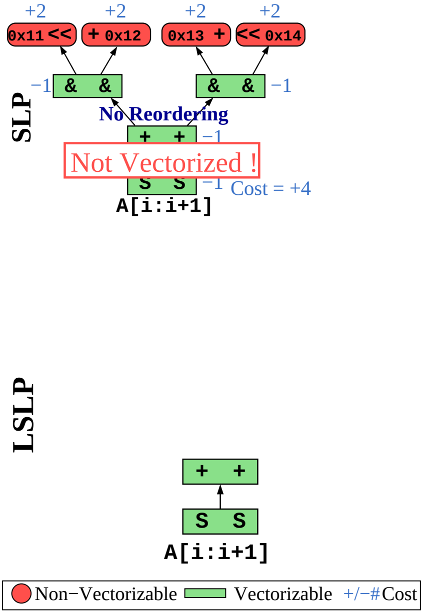


Lane 1 Lane 2



2/3 Opcodes mismatch

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unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
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```

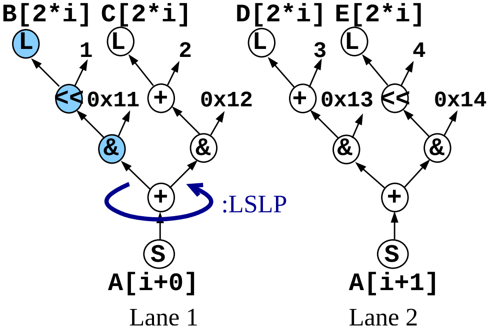

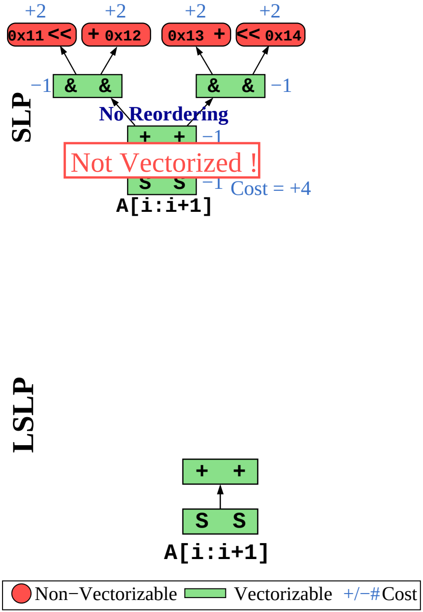

2/3 Opcodes mismatch

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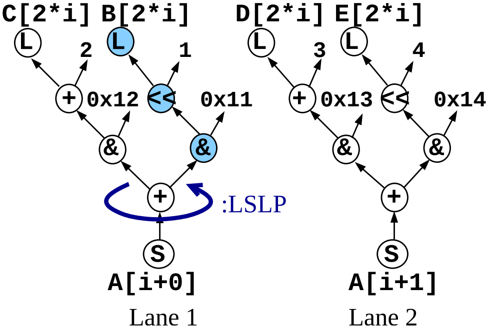

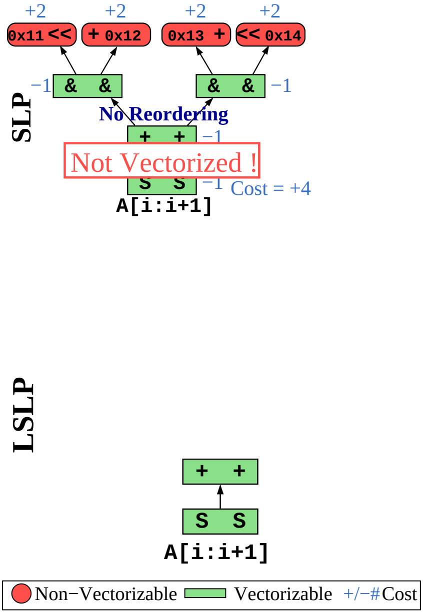

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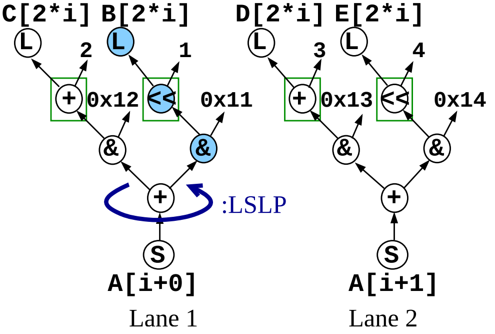

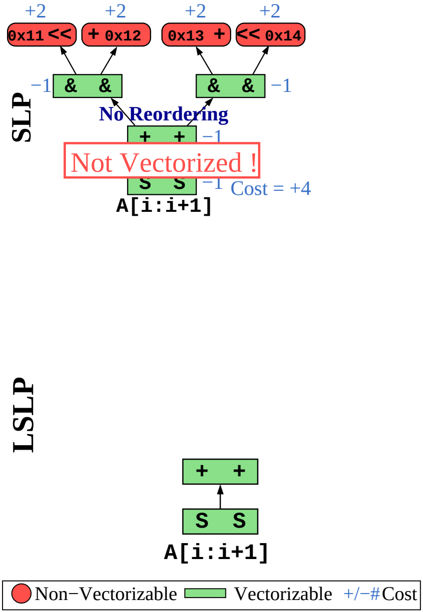

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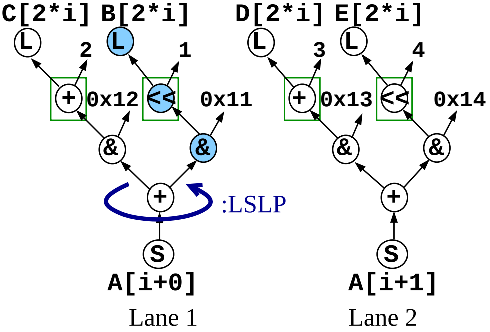
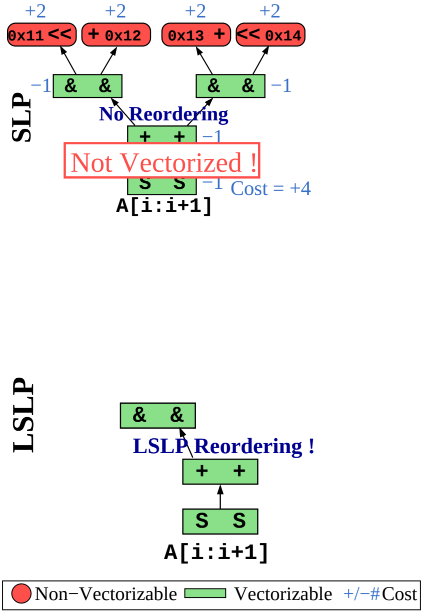
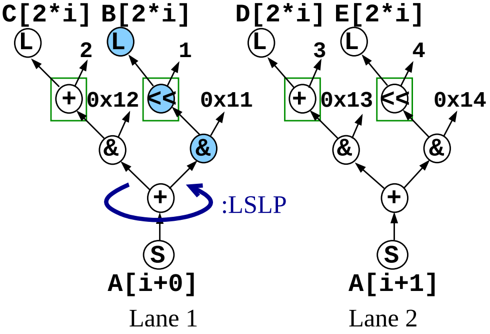
```

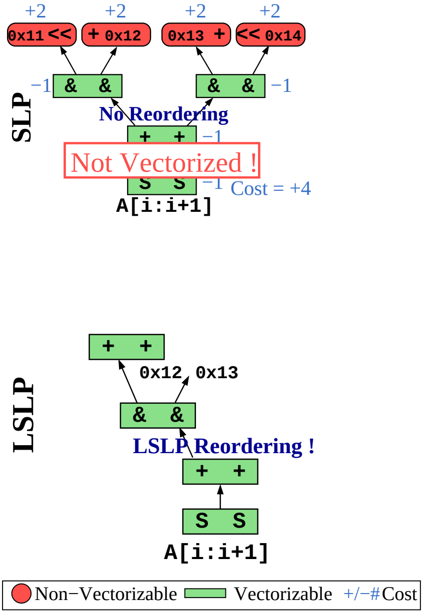




2/3 Opcodes mismatch

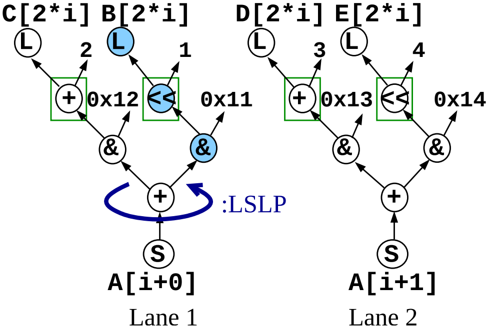
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

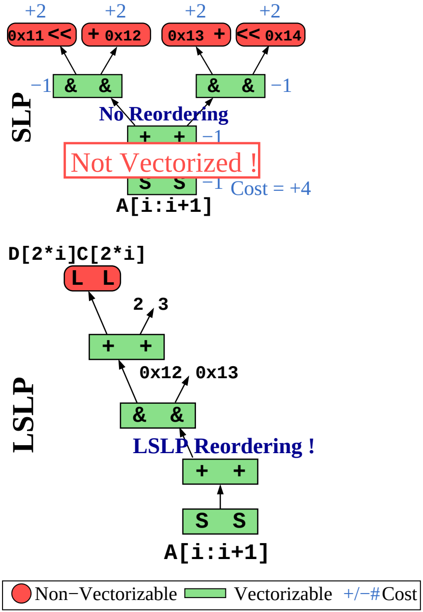




2/3 Opcodes mismatch

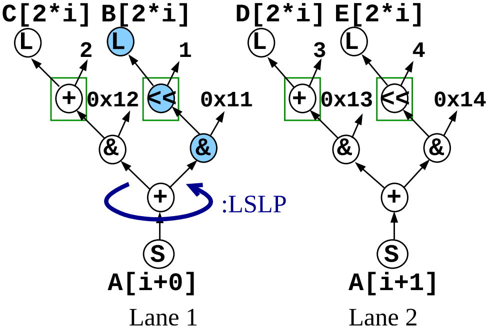
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

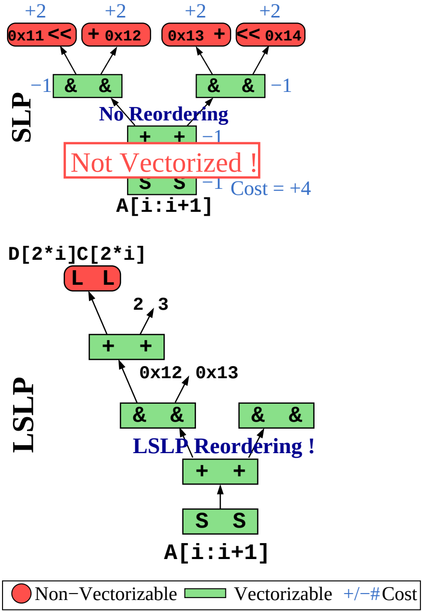




2/3 Opcodes mismatch

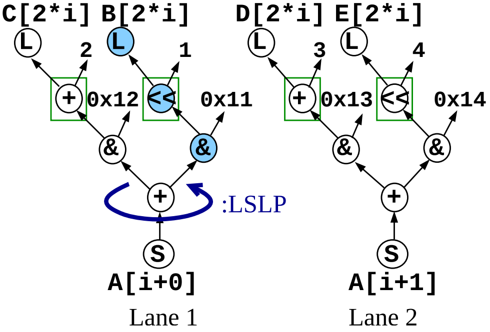
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

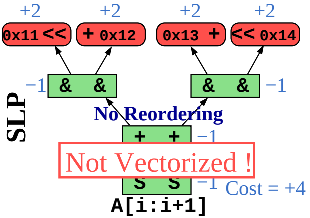


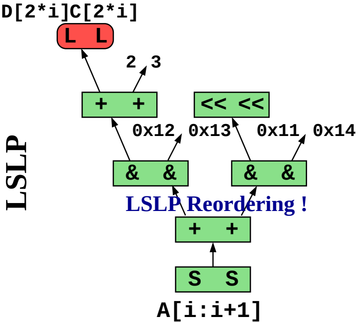


2/3 Opcodes mismatch

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```



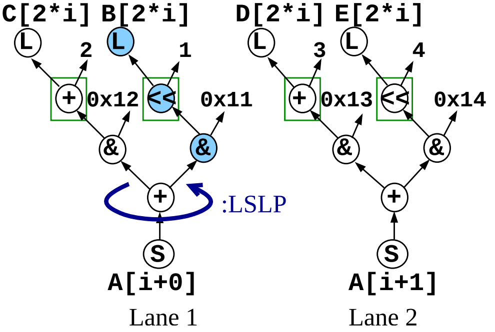


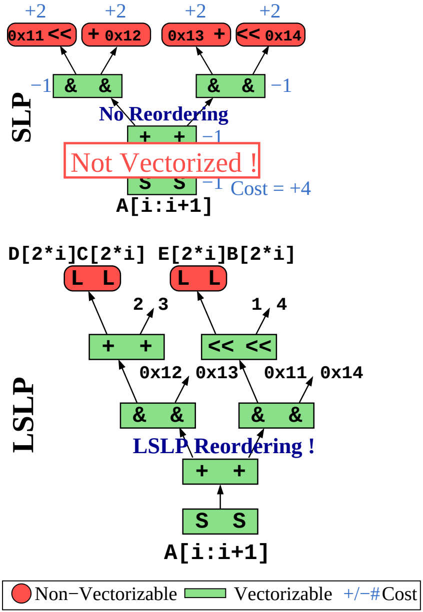


Non−Vectorizable Vectorizable +/−#Cost

2/3 Opcodes mismatch

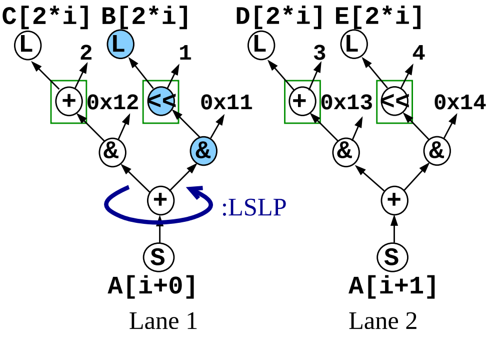
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

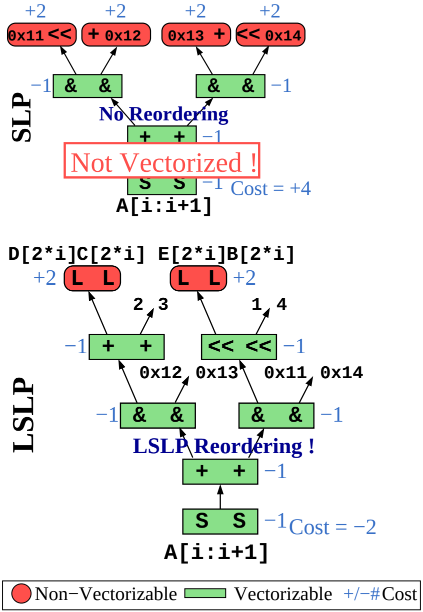




2/3 Opcodes mismatch

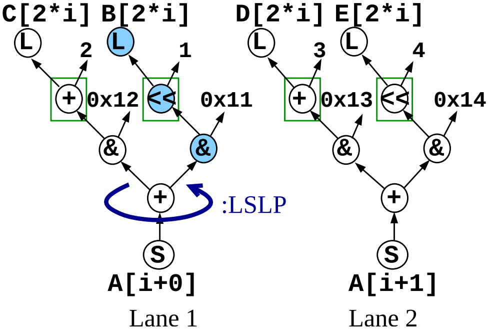
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```

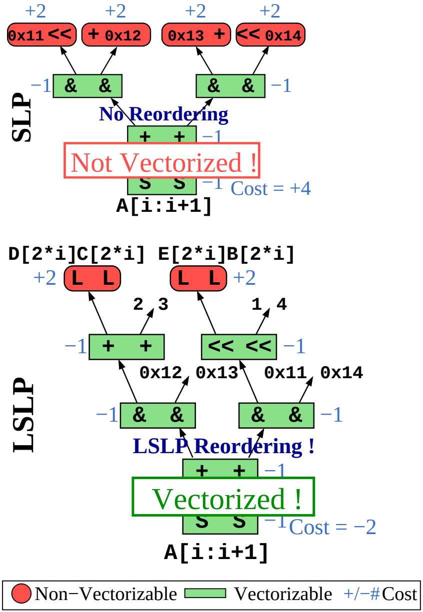




2/3 Opcodes mismatch

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=((B[2*i]<<1)&0x11)+((C[2*i]+ 2)&0x12);
A[i+1]=((D[2*i]+ 3)&0x13)+((E[2*i]<<4)&0x14);
```



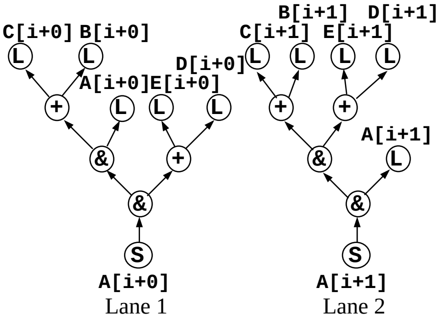


3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

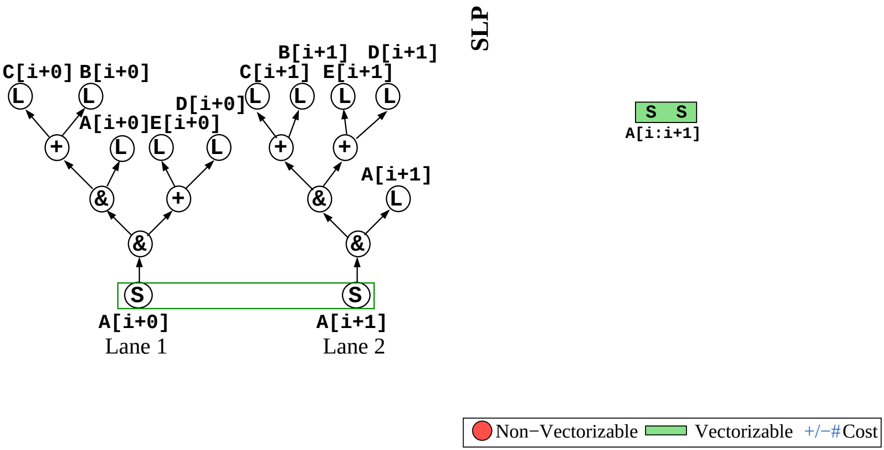
3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



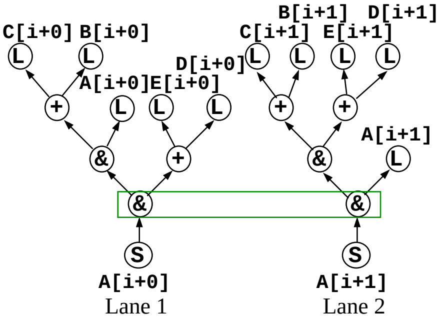
3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

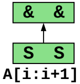


3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



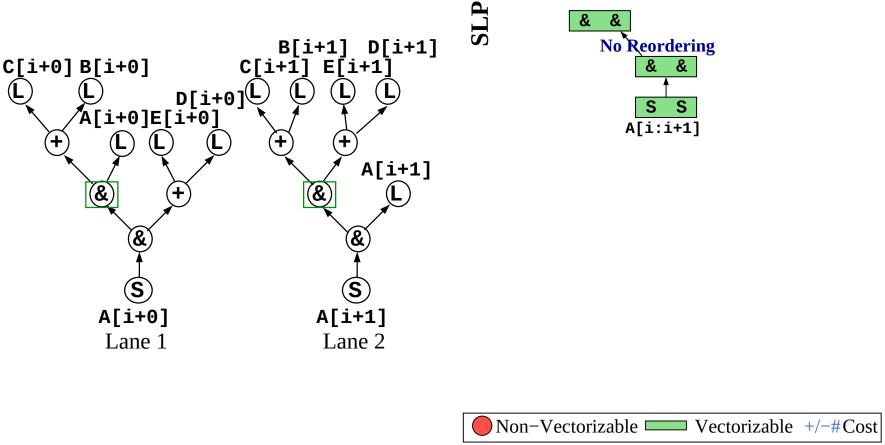
SLP



Non−Vectorizable Vectorizable +/−#Cost

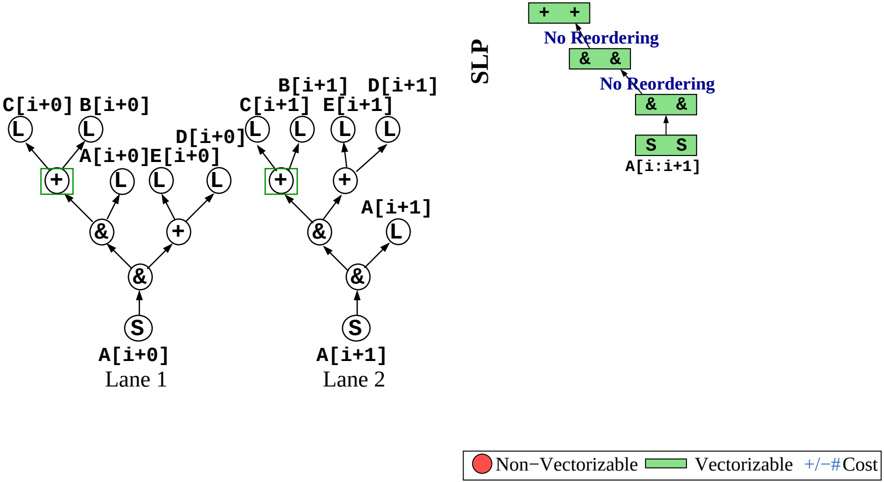
3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



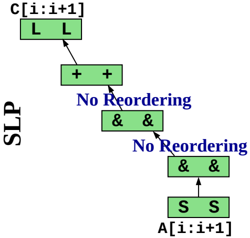
3/3 Chains of Commutative Operations

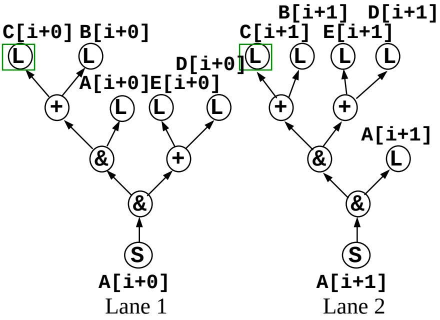
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

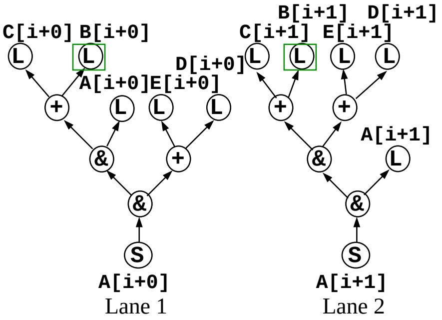


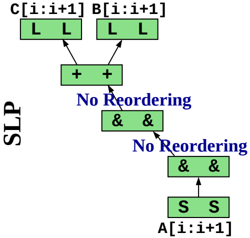


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

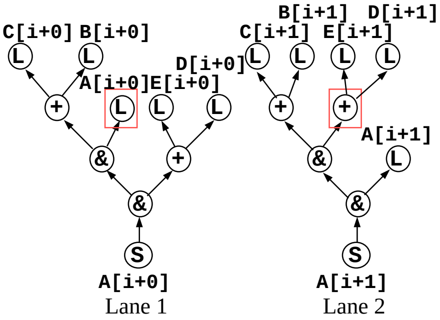


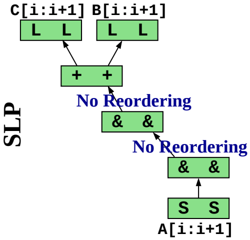


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

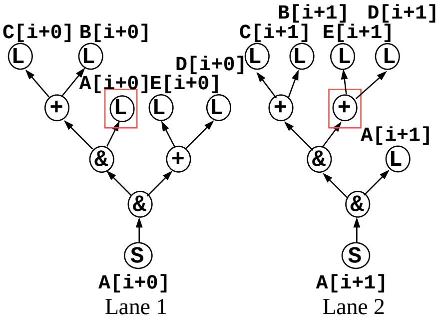


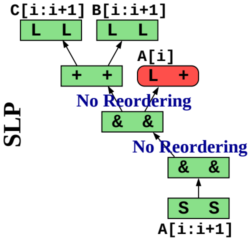


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

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unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```
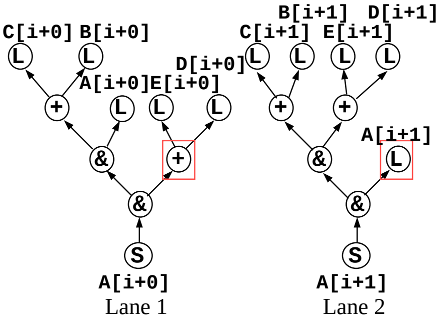
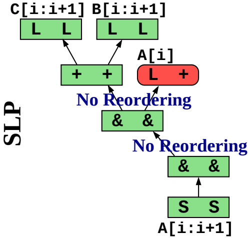
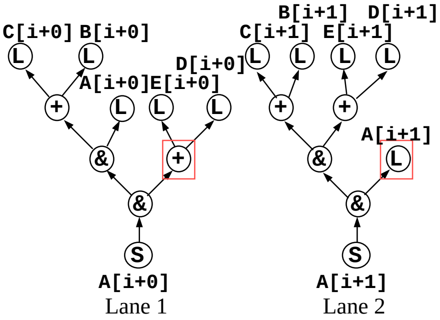



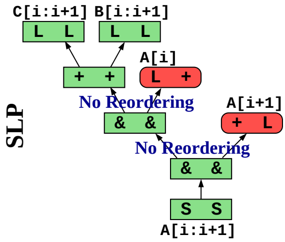


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

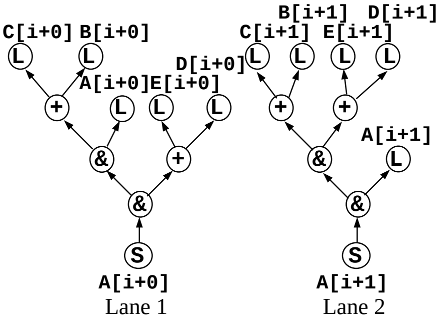


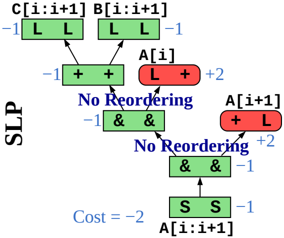


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

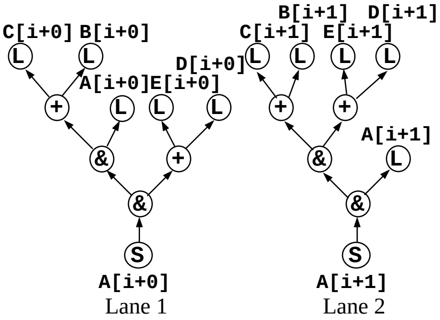


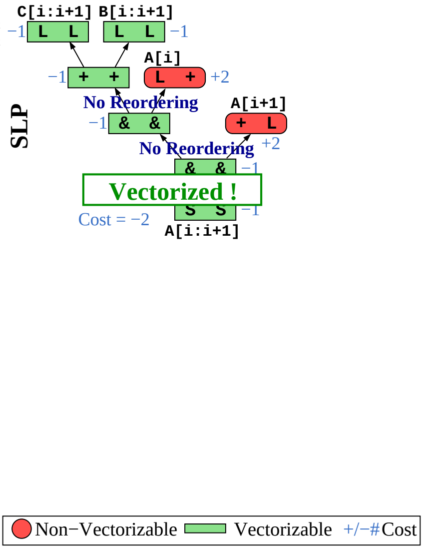


Non−Vectorizable Vectorizable +/−# Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





3/3 Chains of Commutative Operations

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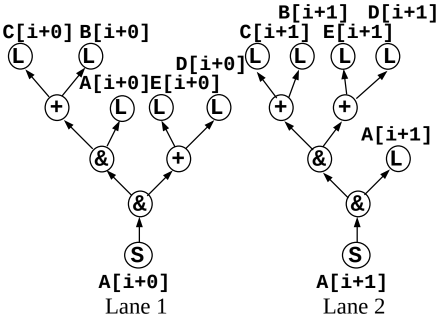
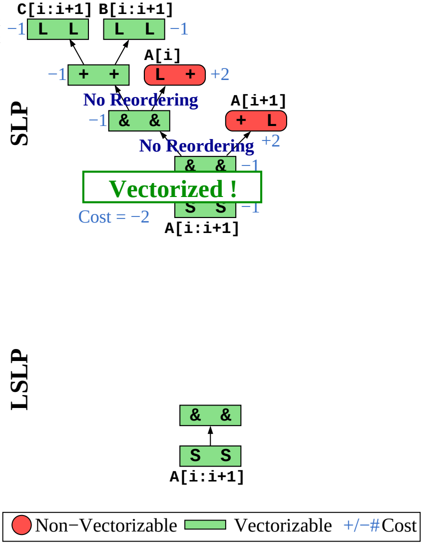
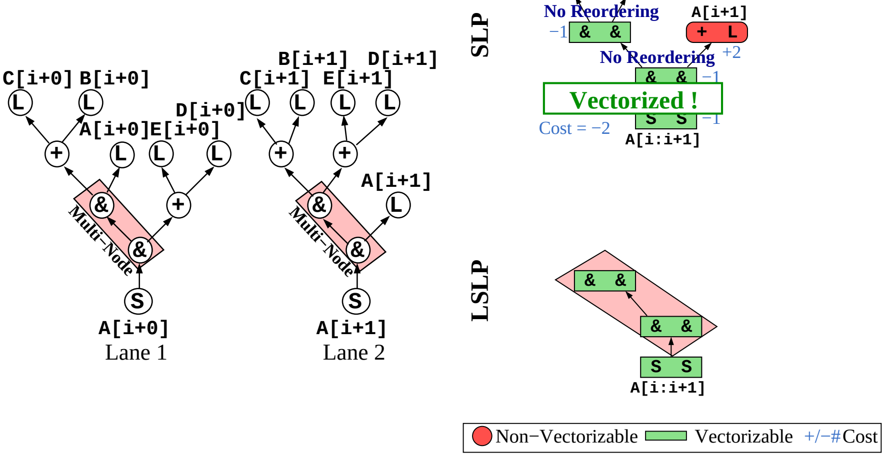
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





3/3 Chains of Commutative Operations

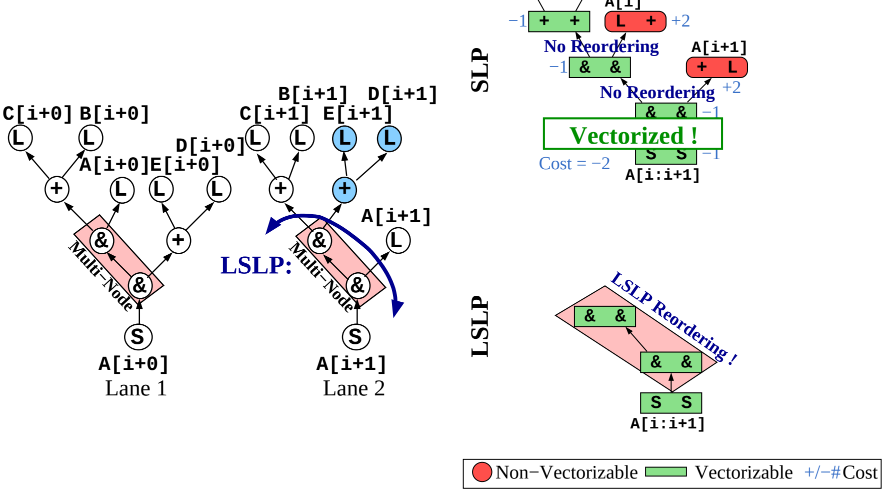
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



 http://vporpo.me

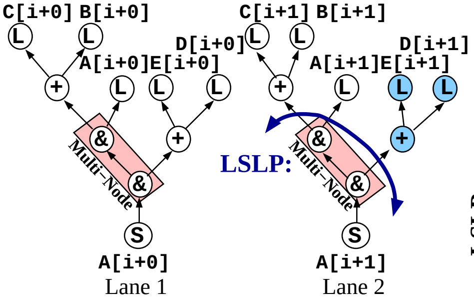
3/3 Chains of Commutative Operations

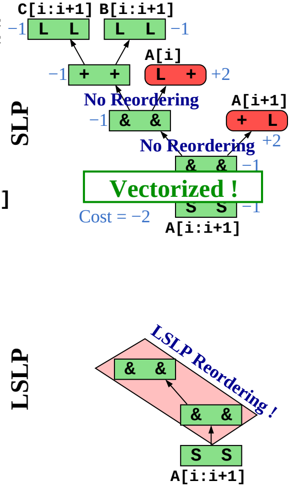
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

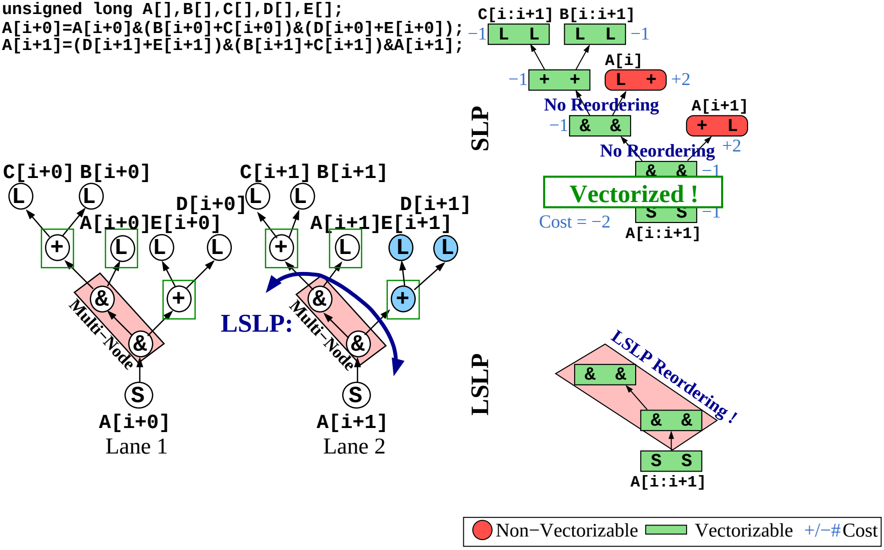




Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

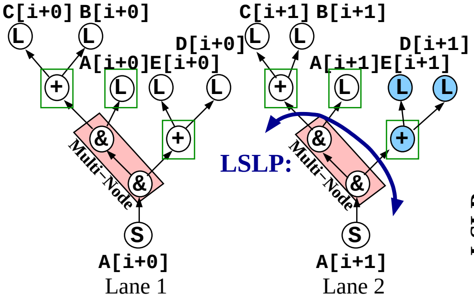
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

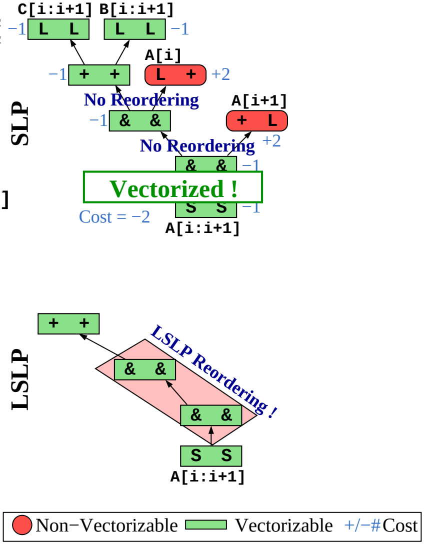


 http://vporpo.me

3/3 Chains of Commutative Operations

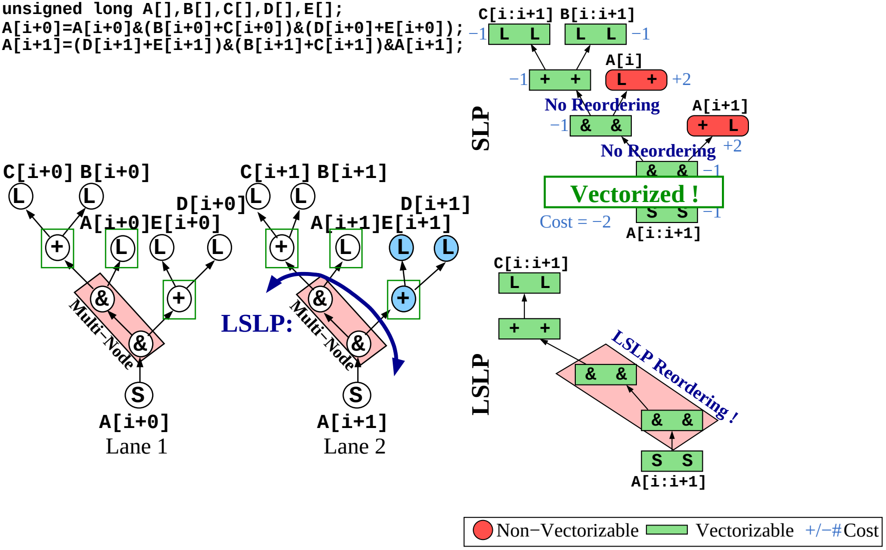
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





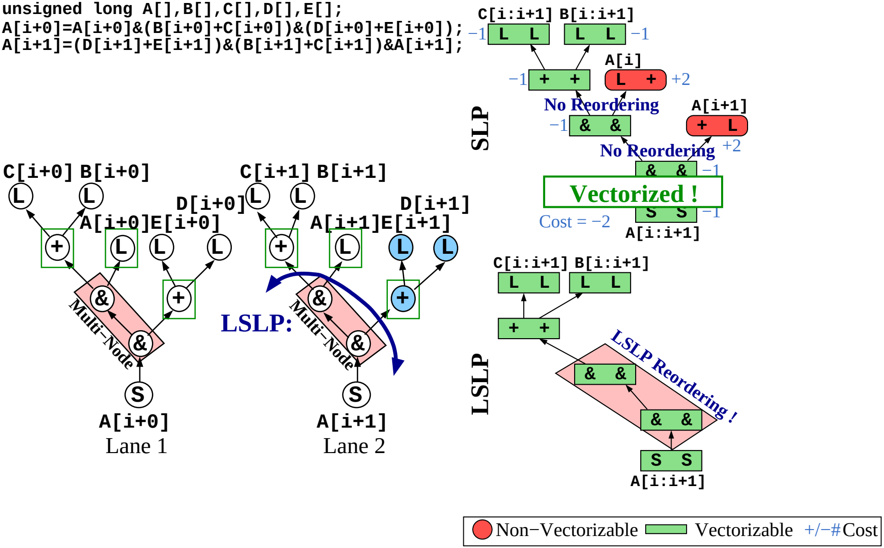
3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



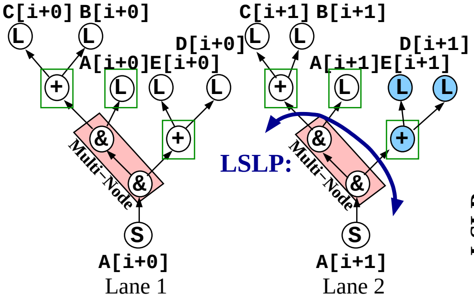
3/3 Chains of Commutative Operations

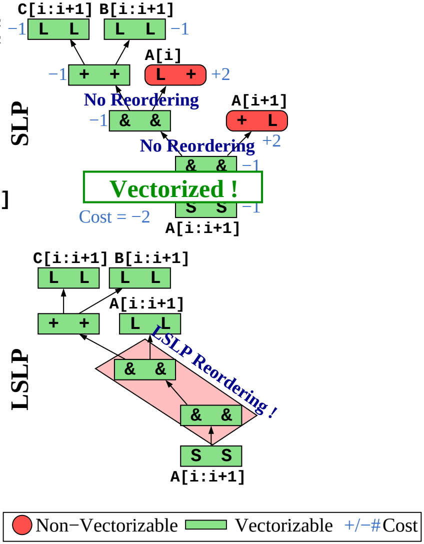
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



3/3 Chains of Commutative Operations

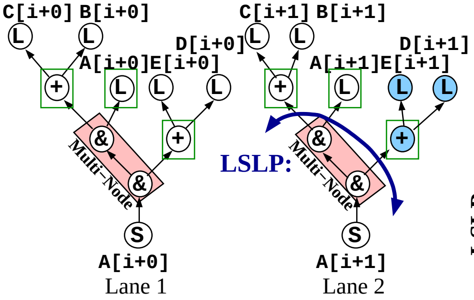
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

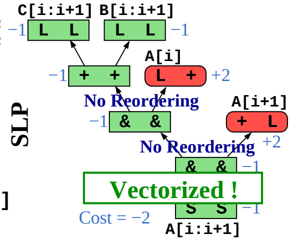


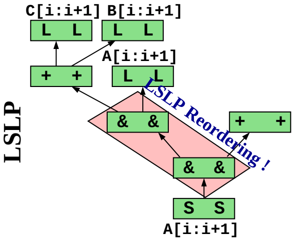


3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```



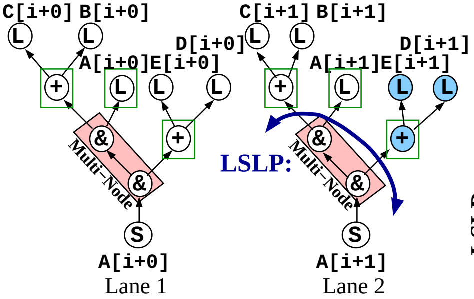


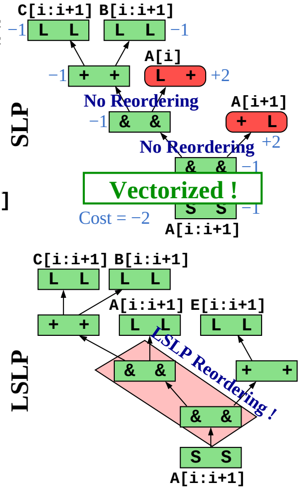


Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





Non−Vectorizable Vectorizable +/−#Cost

3/3 Chains of Commutative Operations

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unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```
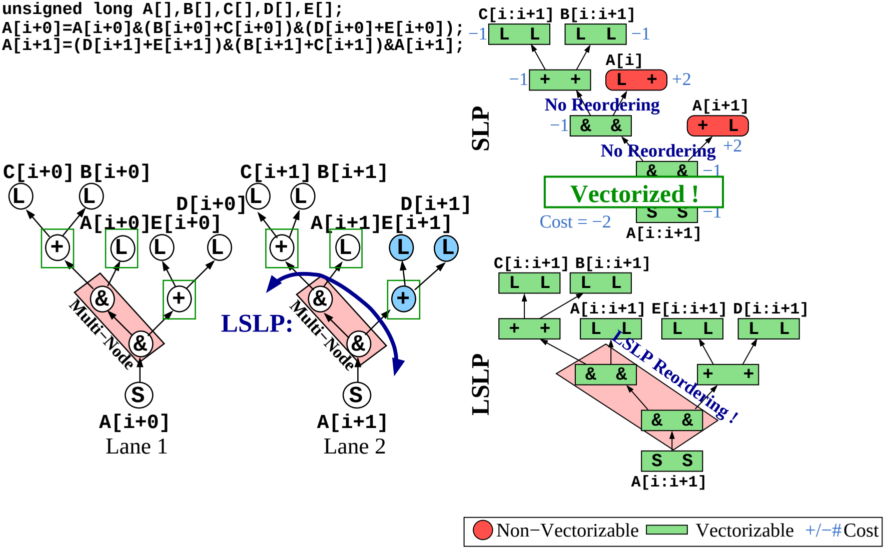
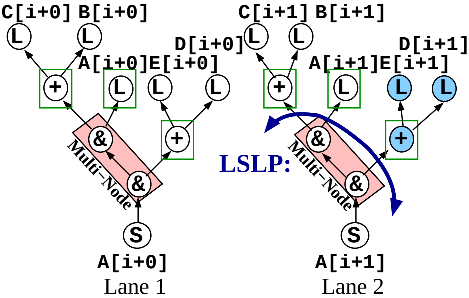
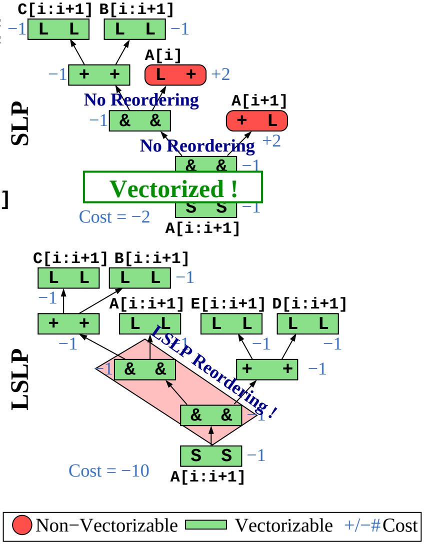



3/3 Chains of Commutative Operations

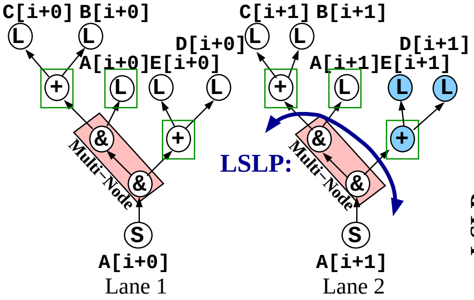
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```

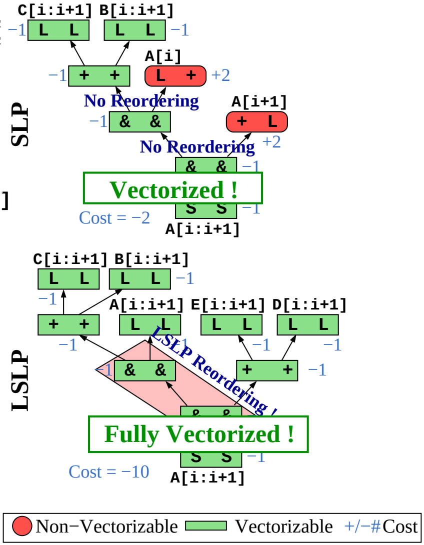




3/3 Chains of Commutative Operations

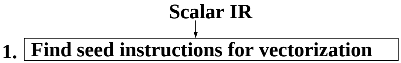
```
unsigned long A[],B[],C[],D[],E[];
A[i+0]=A[i+0]&(B[i+0]+C[i+0])&(D[i+0]+E[i+0]);
A[i+1]=(D[i+1]+E[i+1])&(B[i+1]+C[i+1])&A[i+1];
```





(L)SLP Algorithm

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



(L)SLP Algorithm

- Seed instructions are usually:
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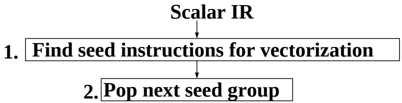
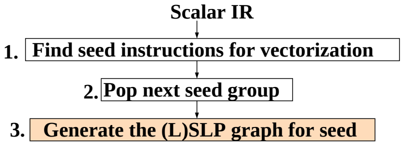


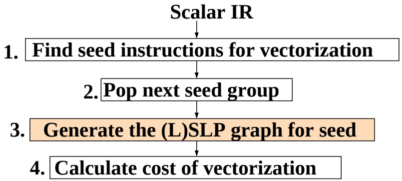
(L)SLP Algorithm

- Seed instructions are usually:
  1. Consecutive Stores
  2. Reductions
- Graph contains groups of vectorizable instructions



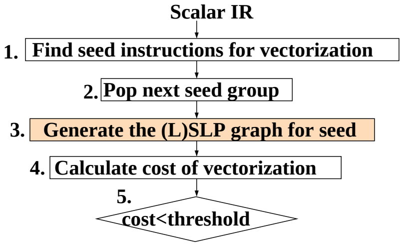
(L)SLP Algorithm

- Seed instructions are usually:
  1. Consecutive Stores
  2. Reductions
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count



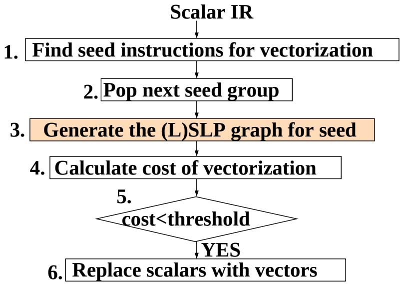
(L)SLP Algorithm

- Seed instructions are usually:
  1. Consecutive Stores
  2. Reductions
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count
- Check overall profitability



(L)SLP Algorithm

- Seed instructions are usually:
  1. Consecutive Stores
  2. Reductions
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count
- Check overall profitability
- Generate vector code



(L)SLP Algorithm

- Seed instructions are usually:
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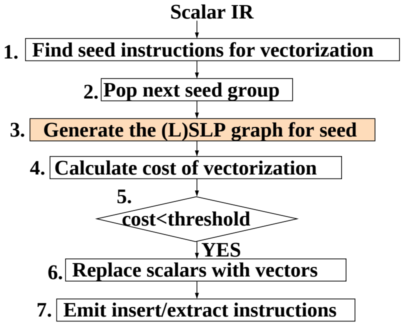

(L)SLP Algorithm

- Seed instructions are usually:
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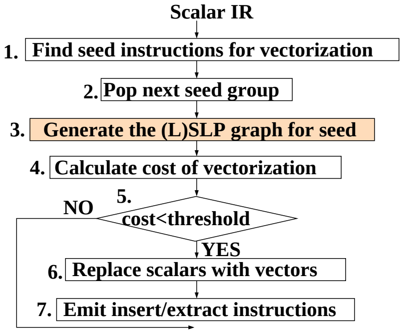

(L)SLP Algorithm

- Seed instructions are usually:
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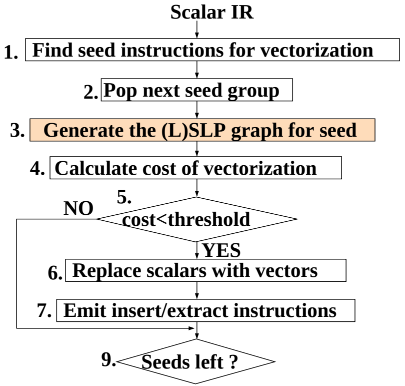
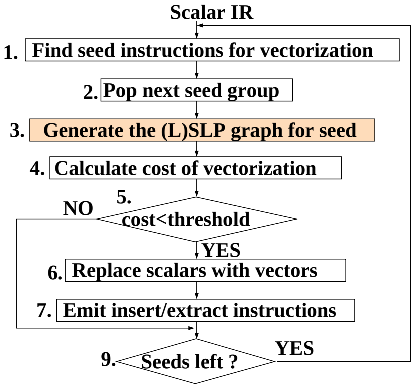


(L)SLP Algorithm

- Seed instructions are usually:
  1. Consecutive Stores
  2. Reductions
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count
- Check overall profitability
- Generate vector code
- Repeat



(L)SLP Algorithm

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  1. Consecutive Stores
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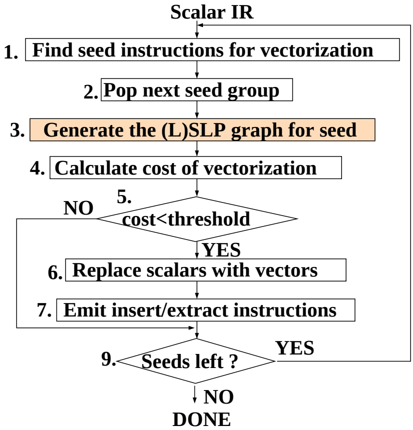
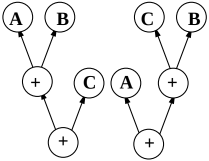
- Graph contains groups of vectorizable instructions
- Cost: weighted instr. count
- Check overall profitability
- Generate vector code
- Repeat



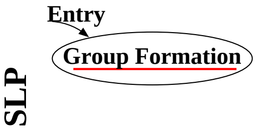
(L)SLP Graph Formation

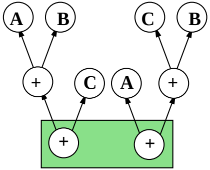
Entry

SLP

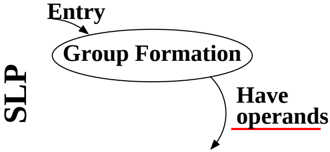


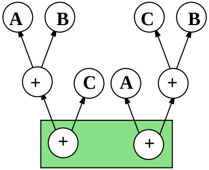
(L)SLP Graph Formation



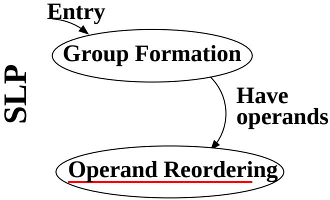


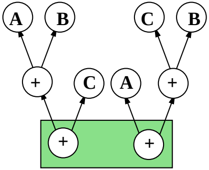
(L)SLP Graph Formation



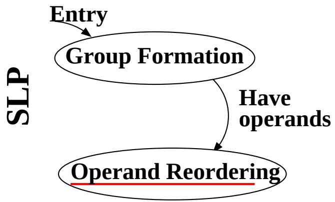


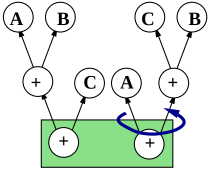
(L)SLP Graph Formation



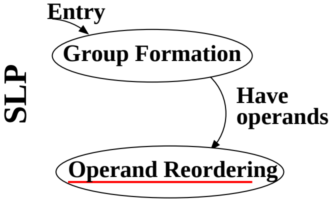


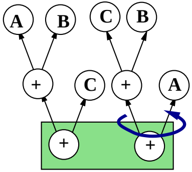
(L)SLP Graph Formation





(L)SLP Graph Formation





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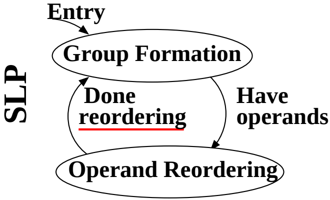
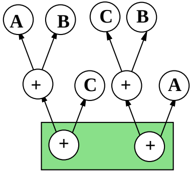
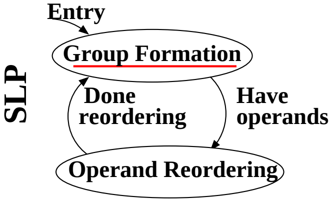
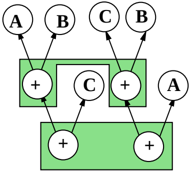


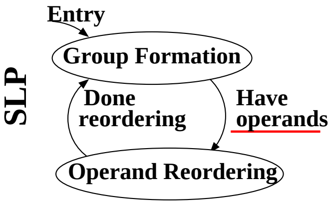


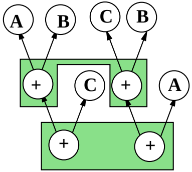
(L)SLP Graph Formation



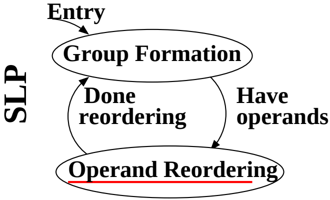


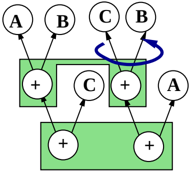
(L)SLP Graph Formation



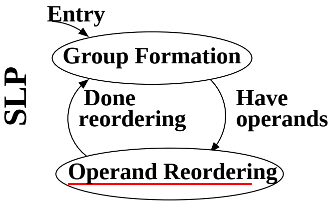


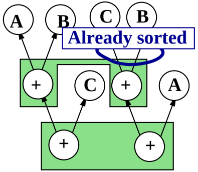
(L)SLP Graph Formation



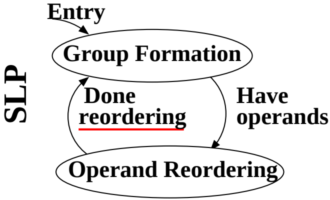


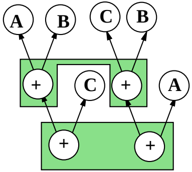
(L)SLP Graph Formation



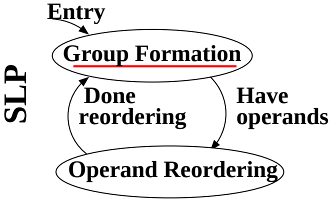


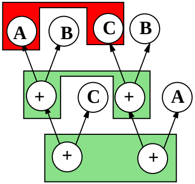
(L)SLP Graph Formation



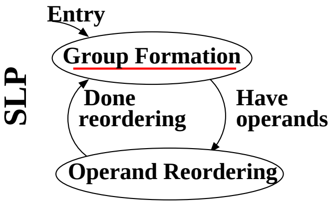


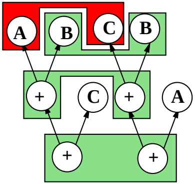
(L)SLP Graph Formation



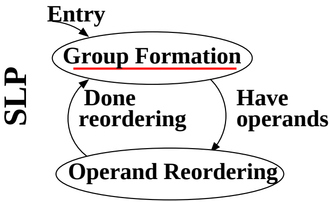


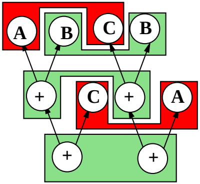
(L)SLP Graph Formation





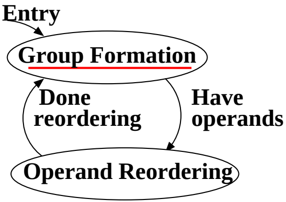
(L)SLP Graph Formation

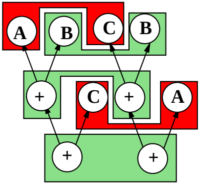




(L)SLP Graph Formation

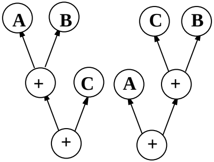
SLP





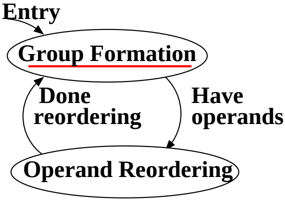
- LSLP: Extended DAG Formation with Multi-Nodes

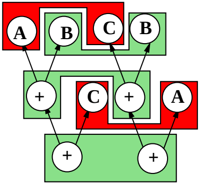
LSLP



(L)SLP Graph Formation

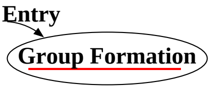
SLP

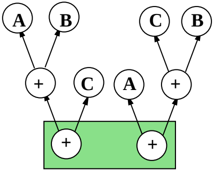




- LSLP: Extended DAG Formation with Multi-Nodes

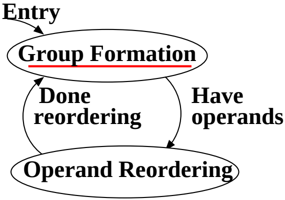
LSLP

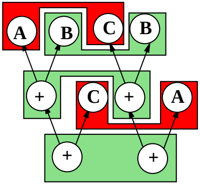




(L)SLP Graph Formation

SLP





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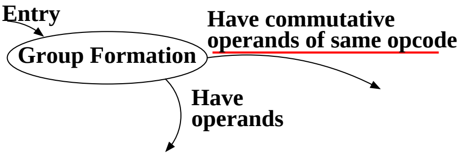
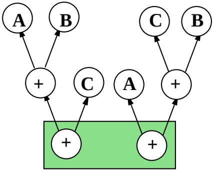
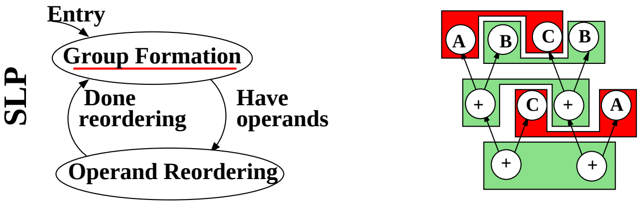
LSLP





(L)SLP Graph Formation



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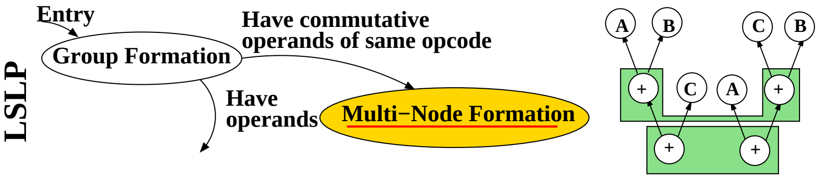
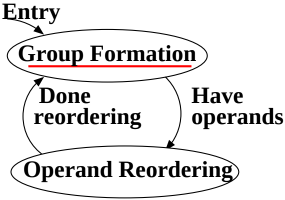
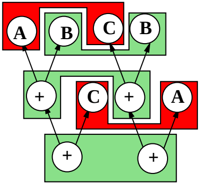


(L)SLP Graph Formation

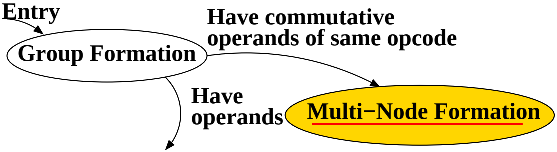
SLP

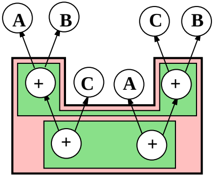




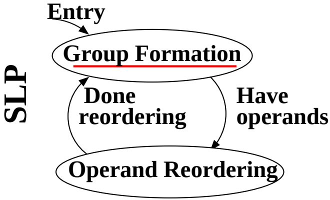
- LSLP: Extended DAG Formation with Multi-Nodes

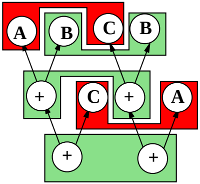
LSLP



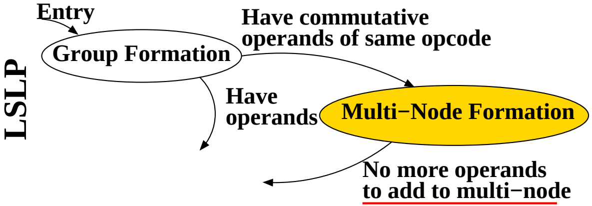


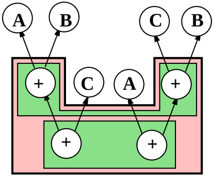
(L)SLP Graph Formation



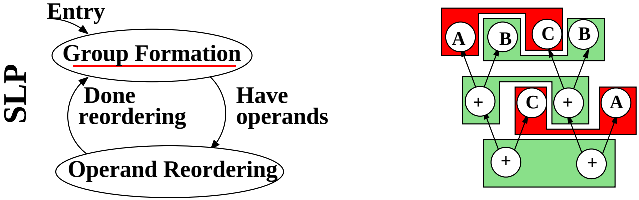


- LSLP: Extended DAG Formation with Multi-Nodes





(L)SLP Graph Formation



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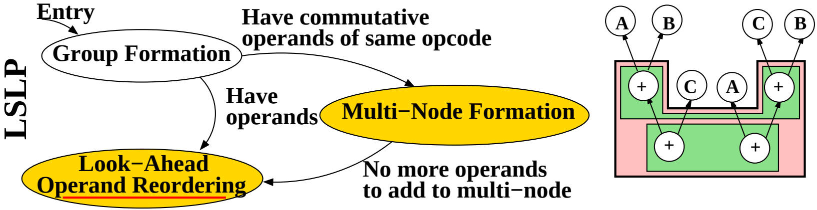
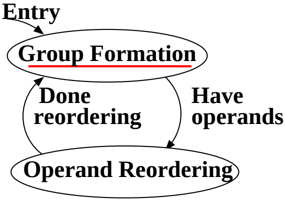
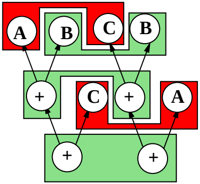


(L)SLP Graph Formation

SLP





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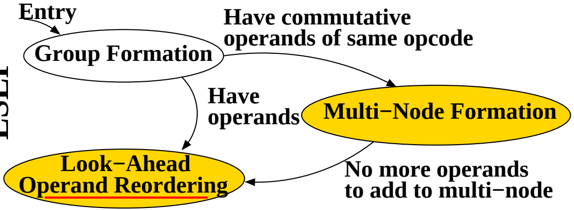
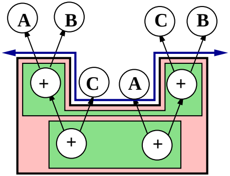
LSLP





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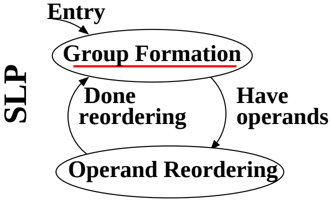

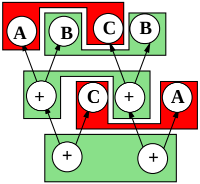

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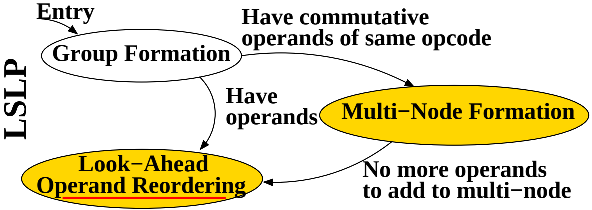
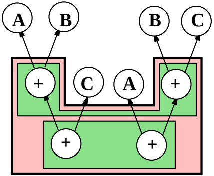
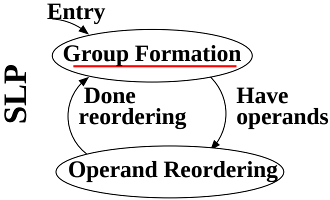
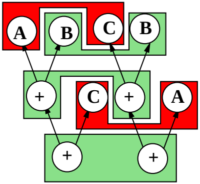




(L)SLP Graph Formation





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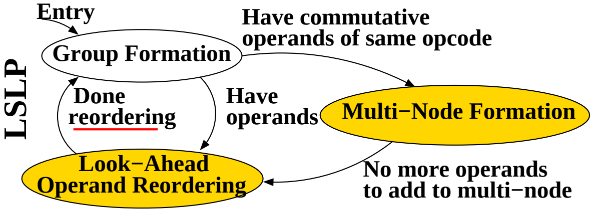
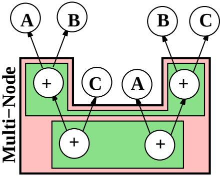
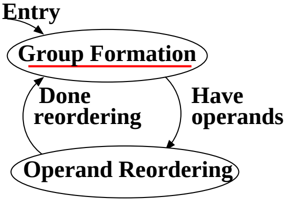
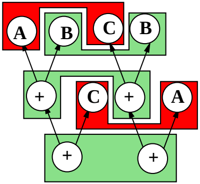




(L)SLP Graph Formation

SLP





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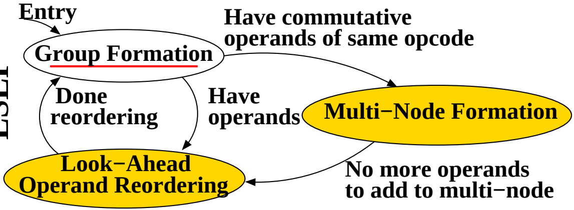
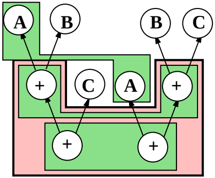
LSLP





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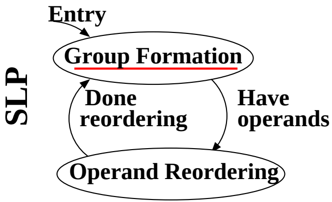

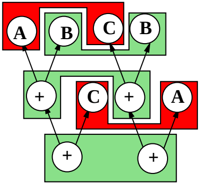

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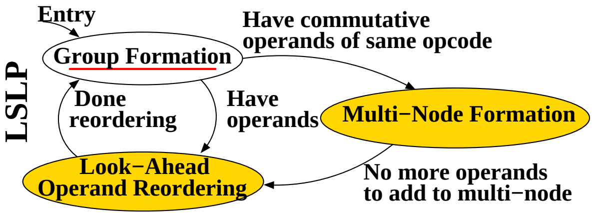

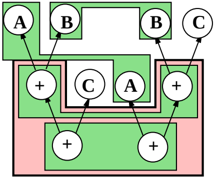

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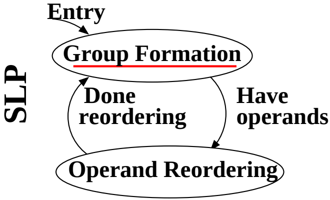

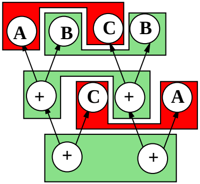

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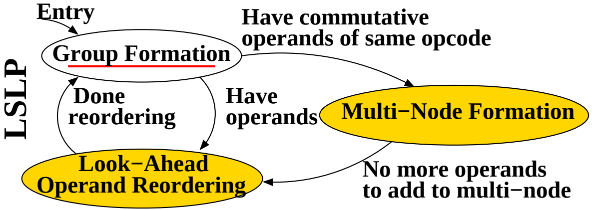
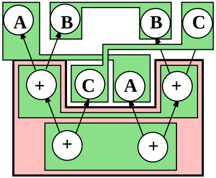
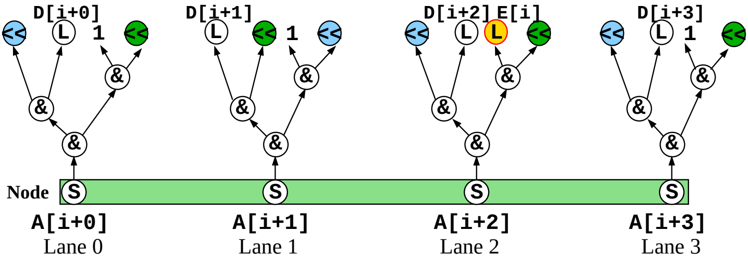
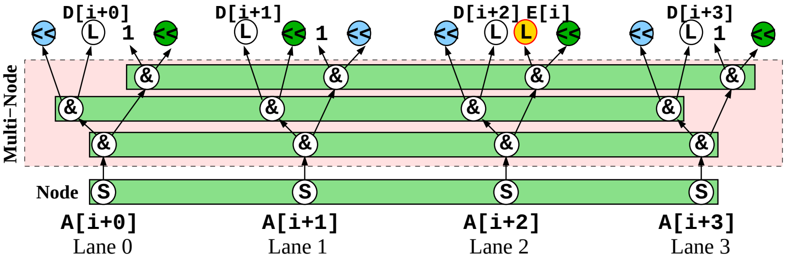




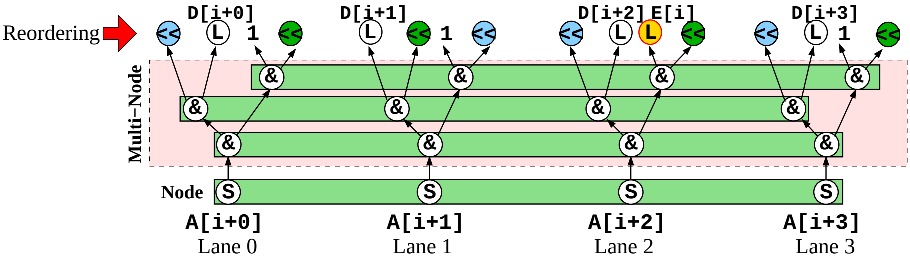
Operand Reordering with Look-Ahead



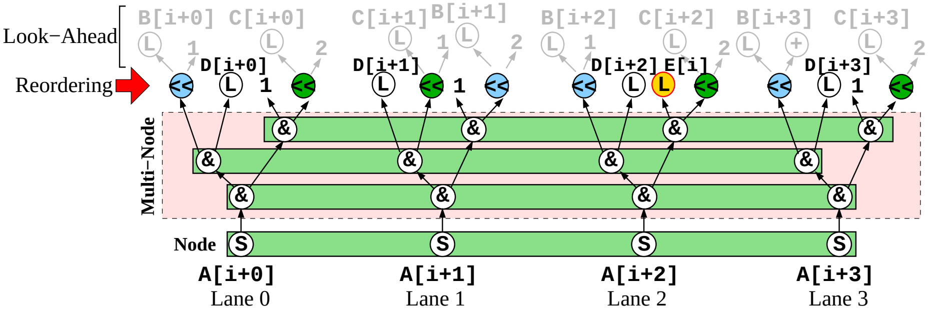
Operand Reordering with Look-Ahead



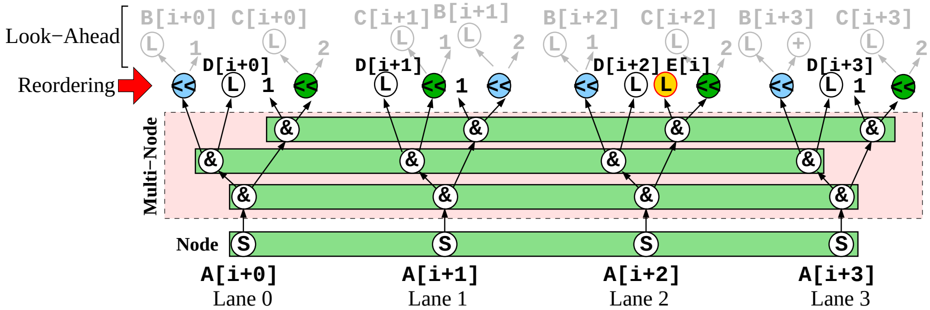
Operand Reordering with Look-Ahead



Operand Reordering with Look-Ahead

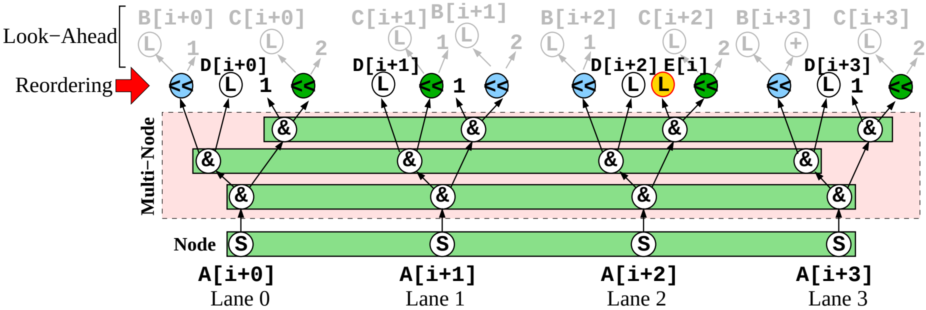


Operand Reordering with Look-Ahead



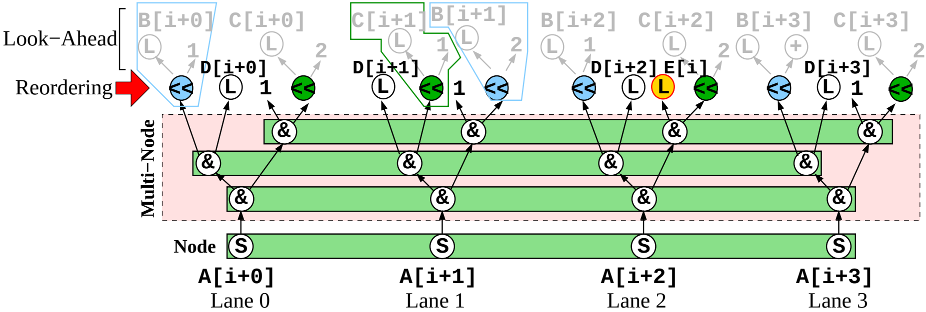
		Lane 0	Lane 1		Lane 2		Lane 3	
		final_order						
Operand Slots	0	<<						
	1	L						
	2	1						
	3	<<						

Operand Reordering with Look-Ahead



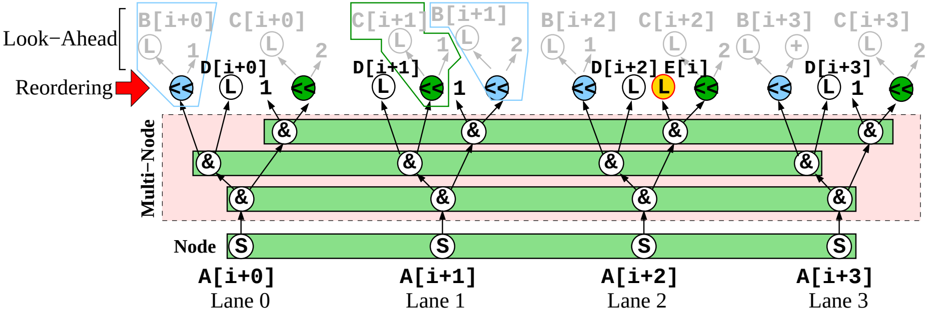
		Lane 0	Lane 1		Lane 2		Lane 3	
		final_order						
Operand Slots	0	<<						
	1	L						
	2	1						
	3	<<						

Operand Reordering with Look-Ahead



Operand Slots	Lane 0	Lane 1		Lane 2		Lane 3	
	final_order	Look−Ahead score		Look−Ahead score		Look−Ahead score	
0	<<	<< <<					
1	L						
2	1						
3	<<						

Operand Reordering with Look-Ahead



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Operand Slots	0	<<	<<:1 <<:2					
	1	L						
	2	1						
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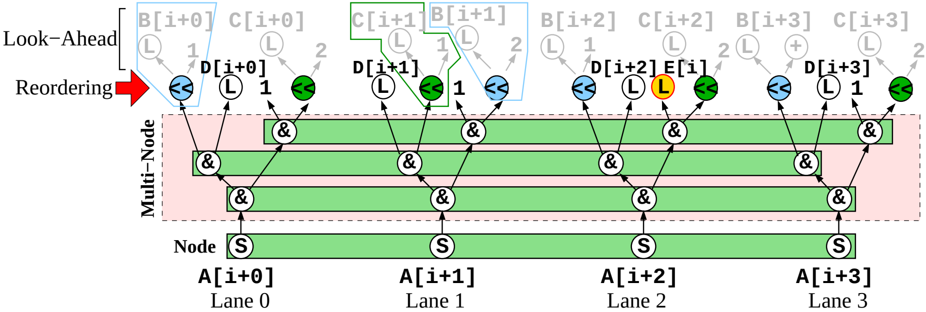
Operand Reordering with Look-Ahead



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Operand Slots	0	<<	<<:1 <<:2					
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	2	1						
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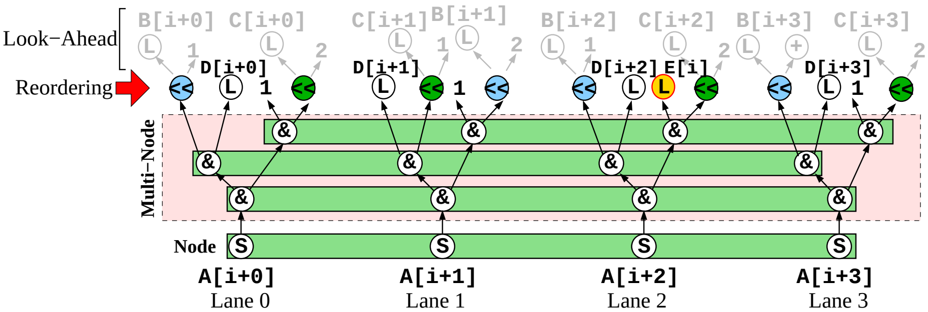
Operand Reordering with Look-Ahead



		Lane 0	Lane 1		Lane 2		Lane 3	
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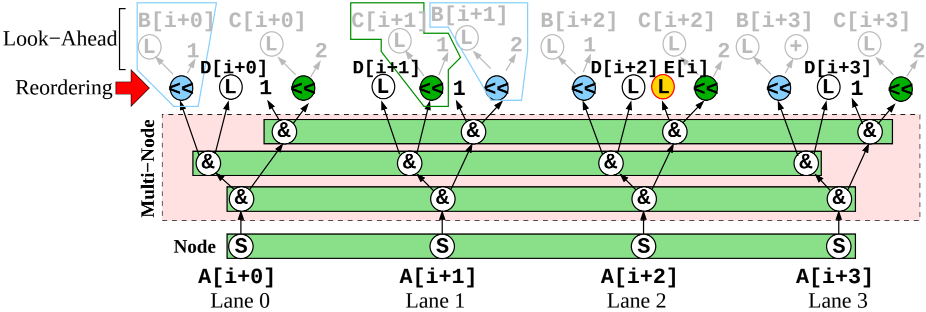
Operand Slots	0	<<	<< :1	<< :2				
	1	L	L :N/A					
	2	1	1 :N/A					
	3	<<						

Operand Reordering with Look-Ahead



	Lane 0	Lane 1		Lane 2		Lane 3	
Operand Slots	final_order	Look−Ahead score		Look−Ahead score		Look−Ahead score	
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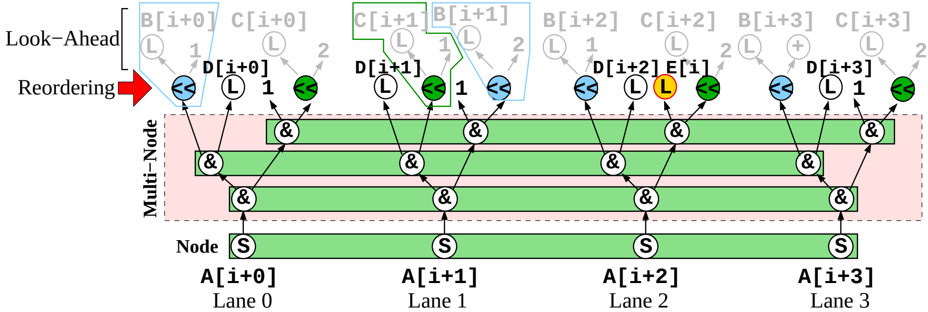
Operand Reordering with Look-Ahead



Operand Slots	Lane 0 final_order	Lane 1 Look−Ahead score	Lane 1	Lane 2 Look−Ahead score	Lane 2	Lane 3 Look−Ahead score	Lane 3
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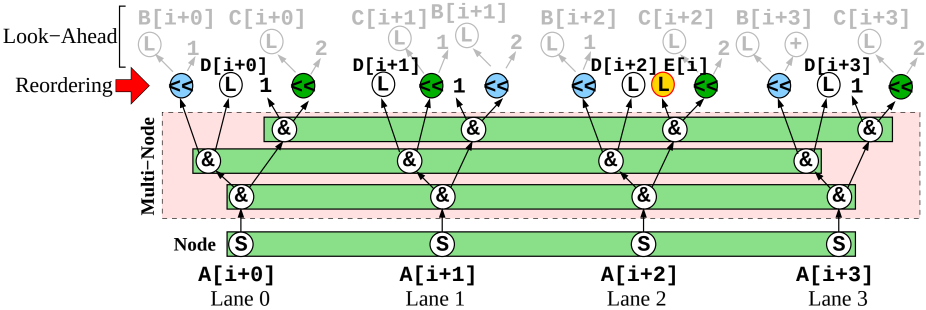
1	L	L :N/A					
2	1	1 :N/A					
3	<<	<<:2 <<:1					

Operand Reordering with Look-Ahead



Operand Slots		Lane 0	Lane 1		Lane 2		Lane 3	
		final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
	0	<<	<<:1 <<:2	<<				
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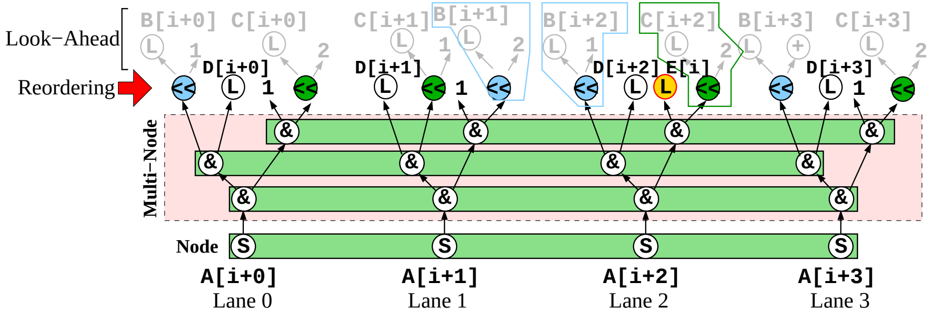
Operand Reordering with Look-Ahead



Operand Slots	Lane 0 final_order	Lane 1 Look−Ahead score	Lane 1 final_order	Lane 2 Look−Ahead score	Lane 2 final_order	Lane 3 Look−Ahead score	Lane 3 final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1			
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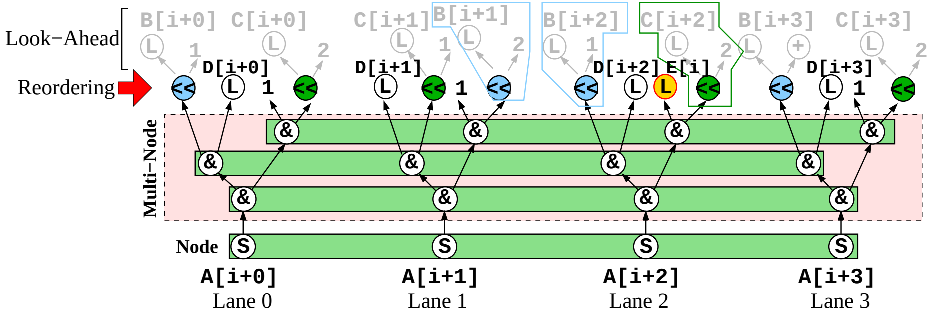
2	1	1 :N/A	1				
3	<<	<<:2 <<:1	<<				

Operand Reordering with Look-Ahead



Operand Slots		Lane 0	Lane 1		Lane 2		Lane 3	
		final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
	0	<<	<<:1 <<:2	<<	<<:2 <<:1			
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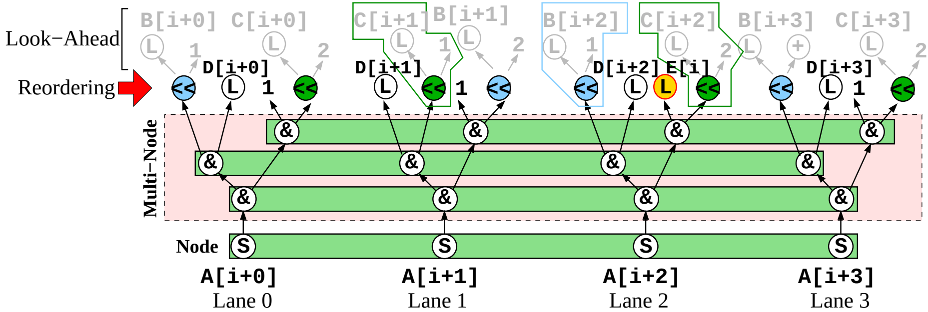
Operand Reordering with Look-Ahead



Operand Slots		Lane 0	Lane 1		Lane 2		Lane 3	
		final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
	0	<<	<<:1 <<:2	<<	<<:2 <<:1			
	1	L	L :N/A	L	L:N/A			
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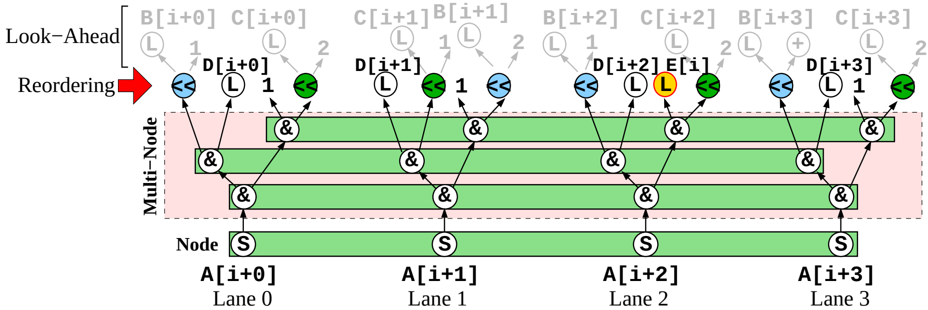
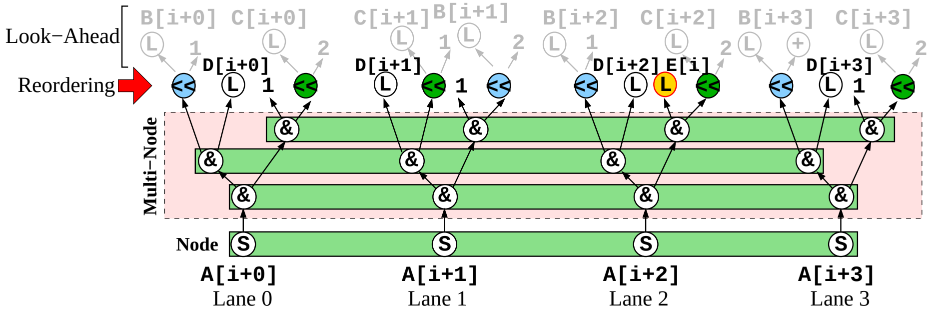
Operand Reordering with Look-Ahead



Operand Slots	Lane 0	Lane 1		Lane 2		Lane 3	
	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<		
1	L	L :N/A	L	L:N/A	L		
2	1	1 :N/A	1	L:N/A	L		
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<		

Operand Reordering with Look-Ahead



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	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<		
1	L	L :N/A	L	L:N/A	L		
2	1	1 :N/A	1	L:N/A	FAILED		
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<		

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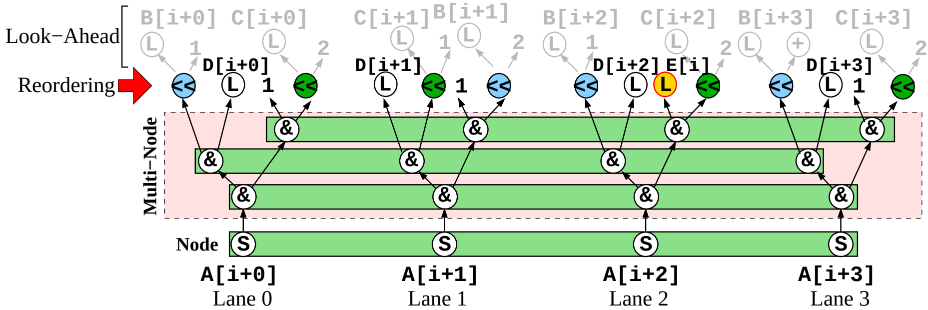

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1	L	L :N/A	L	L:N/A	L	L:N/A	
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	

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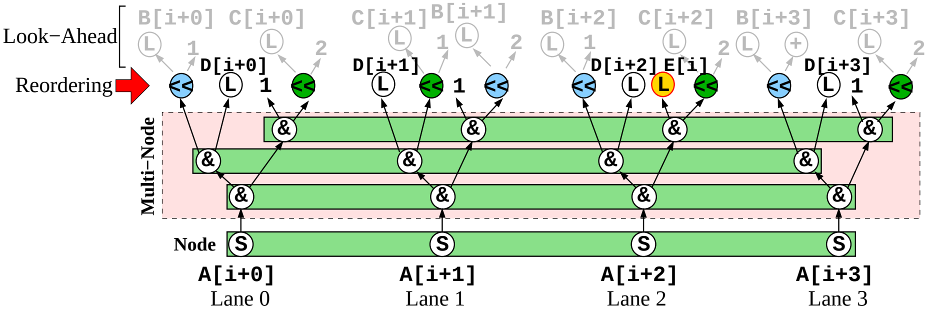

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0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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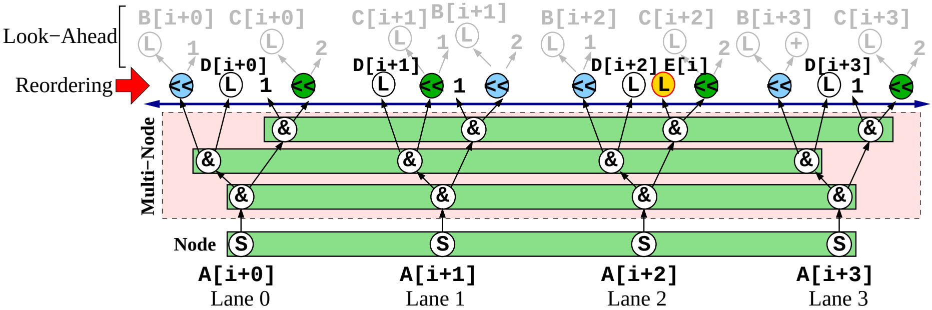

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	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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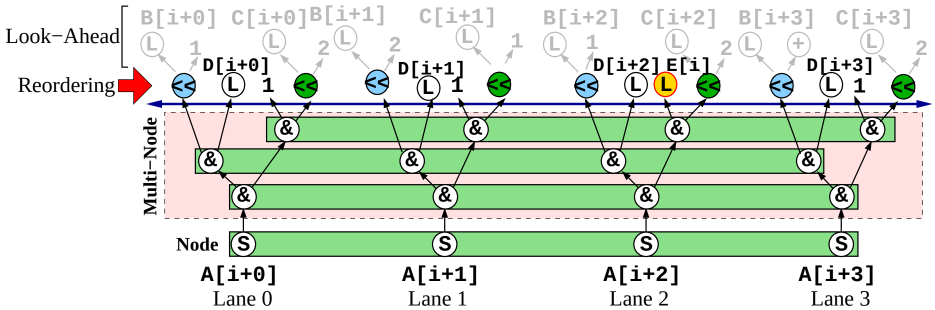

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Operand Slots		final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
	0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
	1	L	L :N/A	L	L:N/A	L	L:N/A	L
	2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
	3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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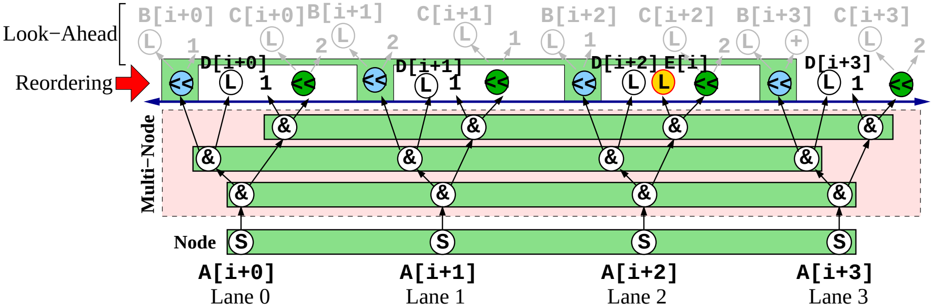

Operand Slots	Lane 0 final_order	Lane 1 Look−Ahead score	Lane 1 final_order	Lane 2 Look−Ahead score	Lane 2 final_order	Lane 3 Look−Ahead score	Lane 3 final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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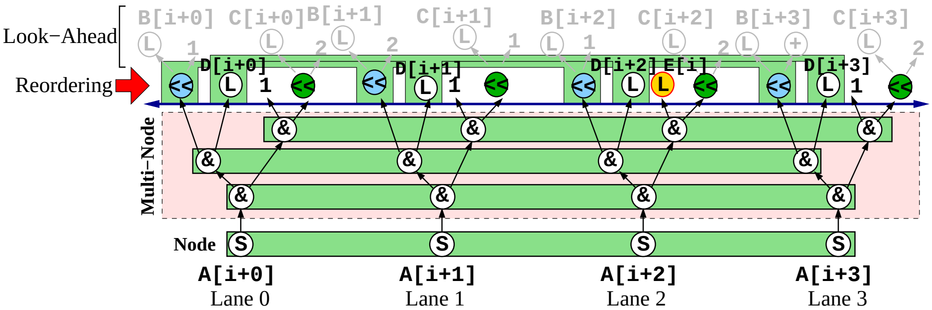

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Operand Slots	0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
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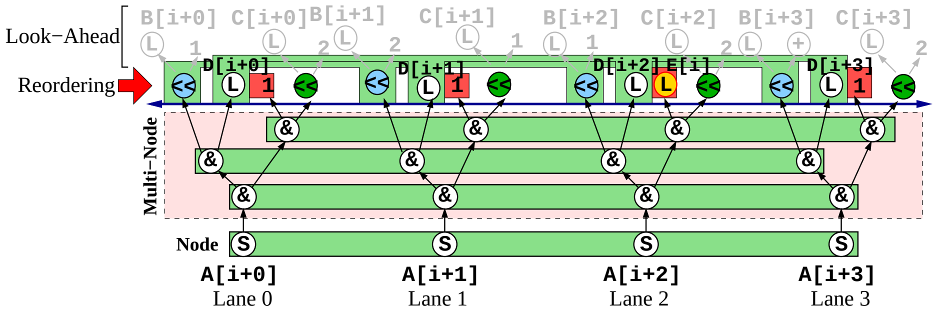

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0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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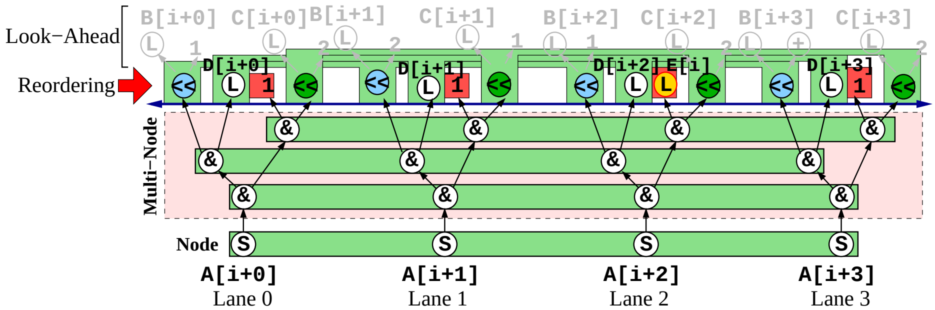

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1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

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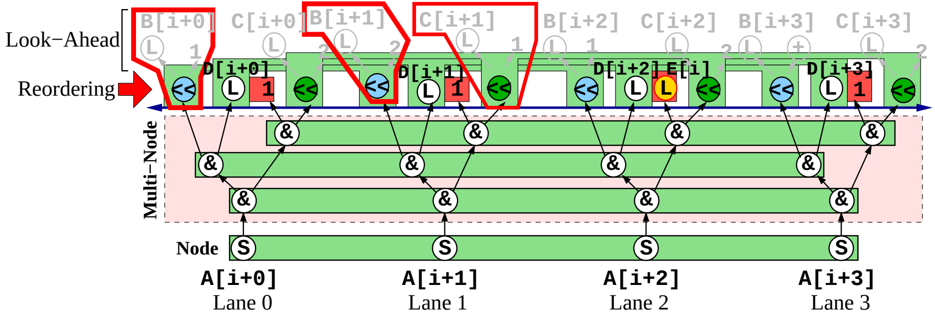

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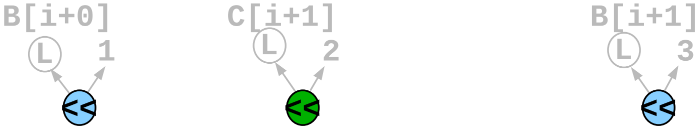
	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order	Look−Ahead score	final_order
0	<<	<<:1 <<:2	<<	<<:2 <<:1	<<	<<:1 <<:1	<<
1	L	L :N/A	L	L:N/A	L	L:N/A	L
2	1	1 :N/A	1	L:N/A	FAILED	1 :N/A	1
3	<<	<<:2 <<:1	<<	<<:1 <<:2	<<	<<:0 <<:2	<<

Score Calculation with Look-Ahead

slot 0

Lane 0 | **Lane 1 Candidates**



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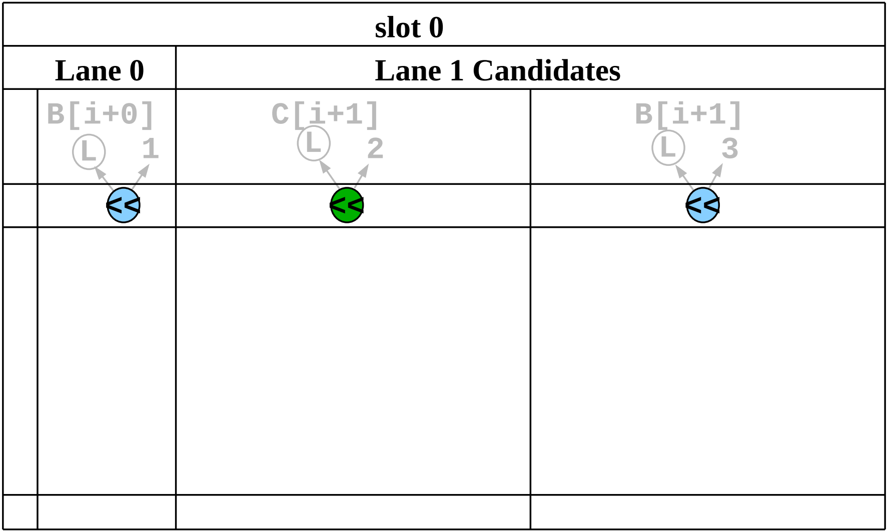

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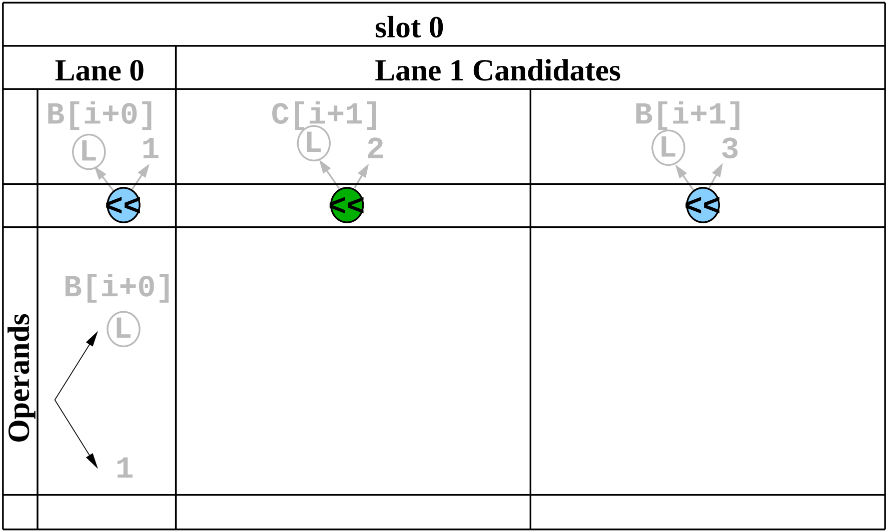

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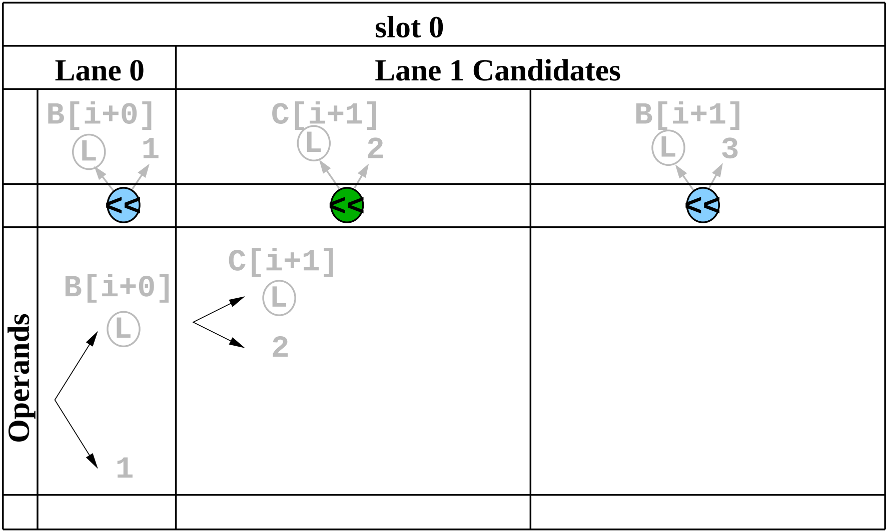

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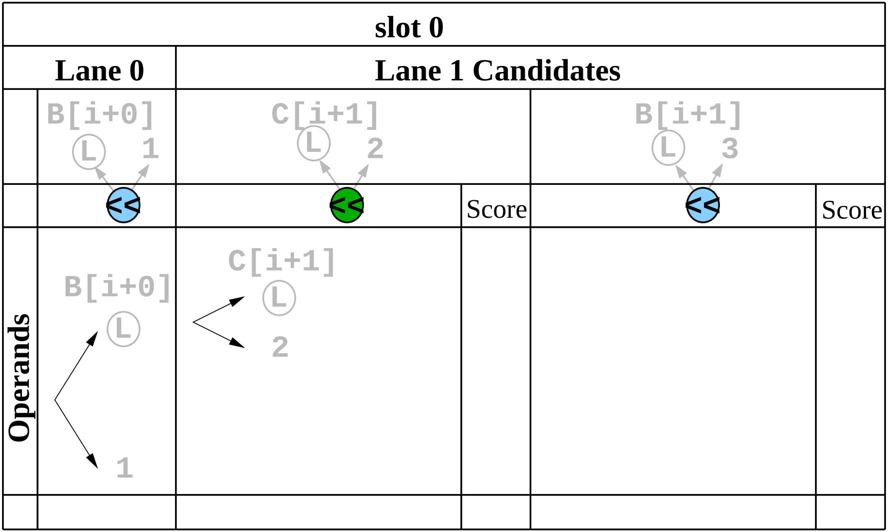

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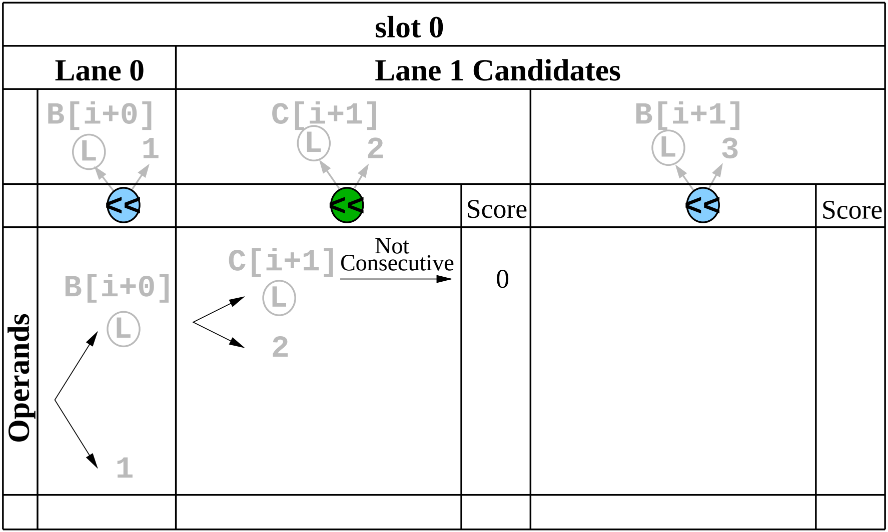

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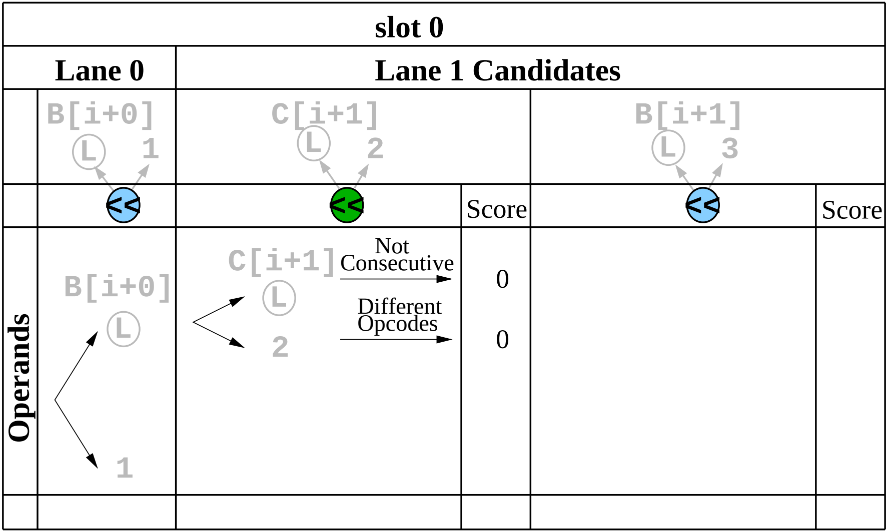

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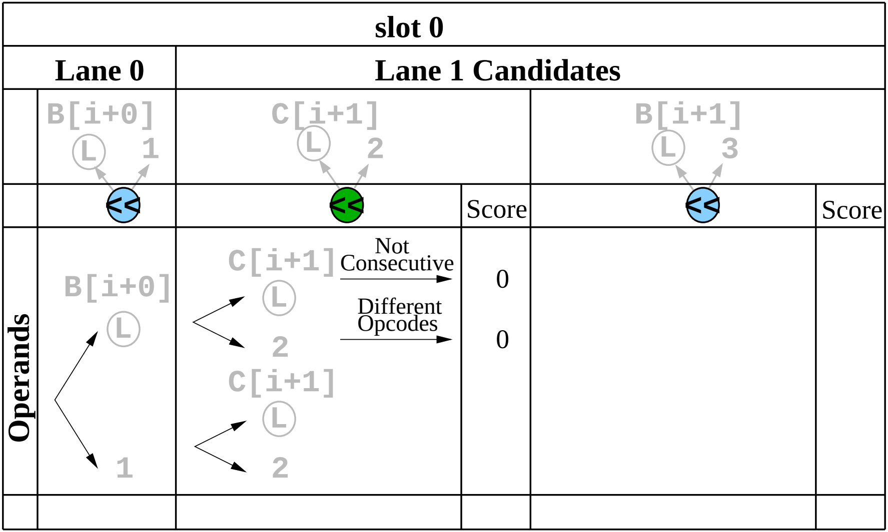

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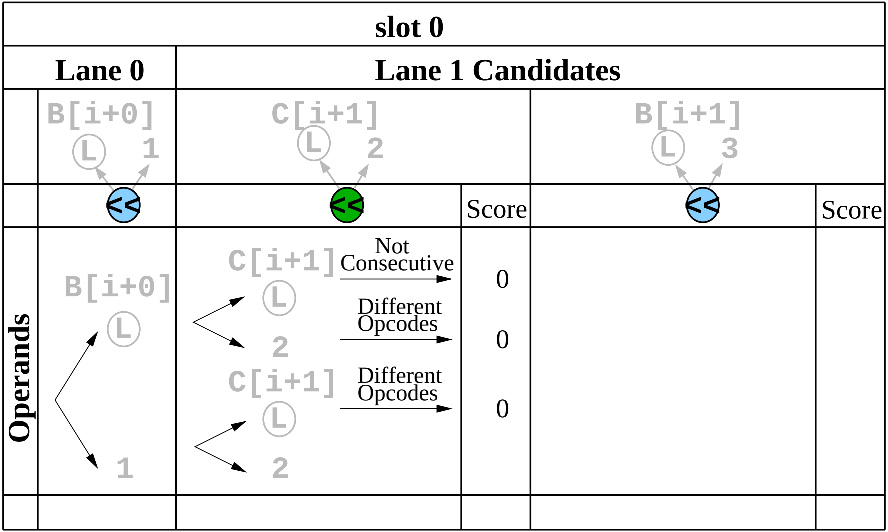

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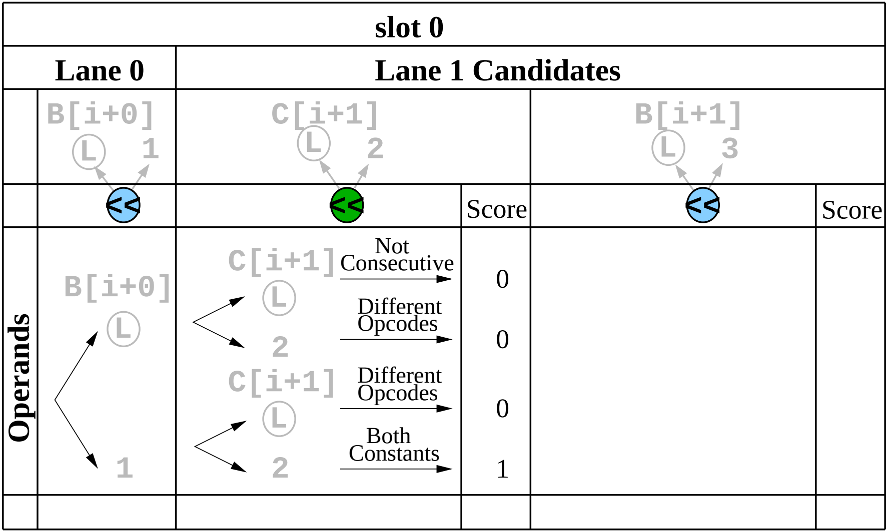

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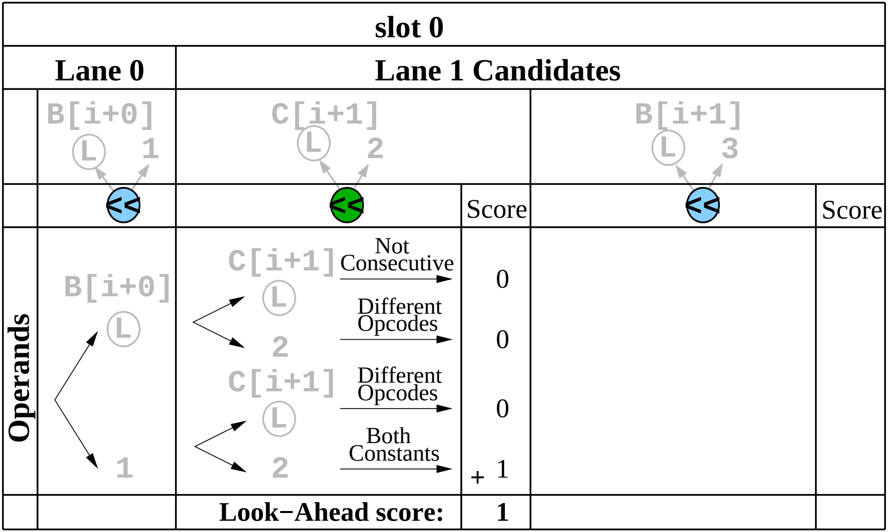

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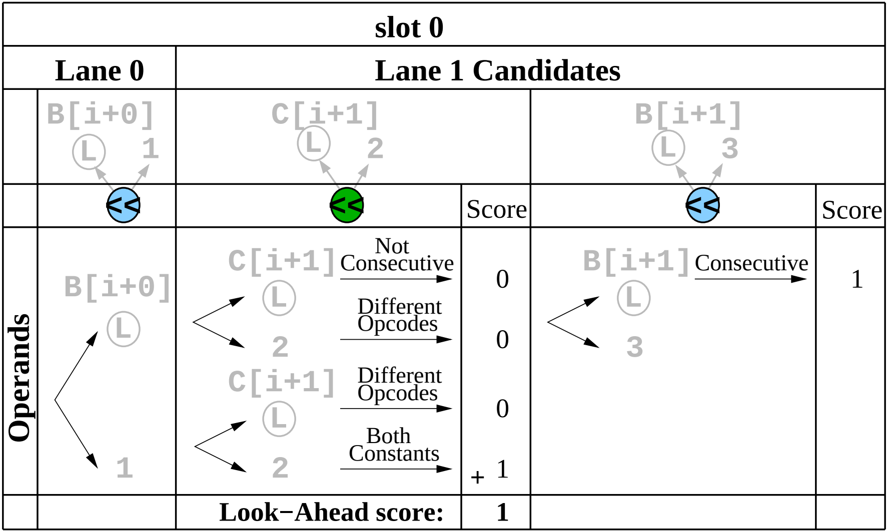

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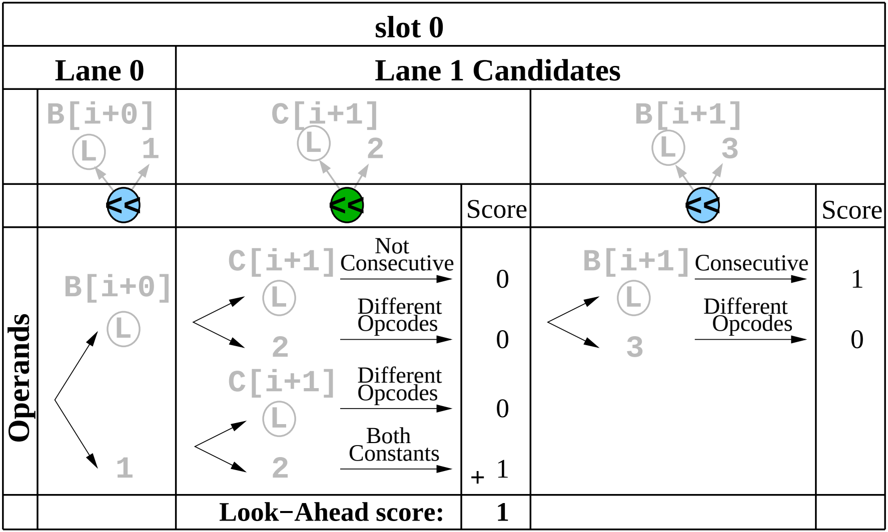

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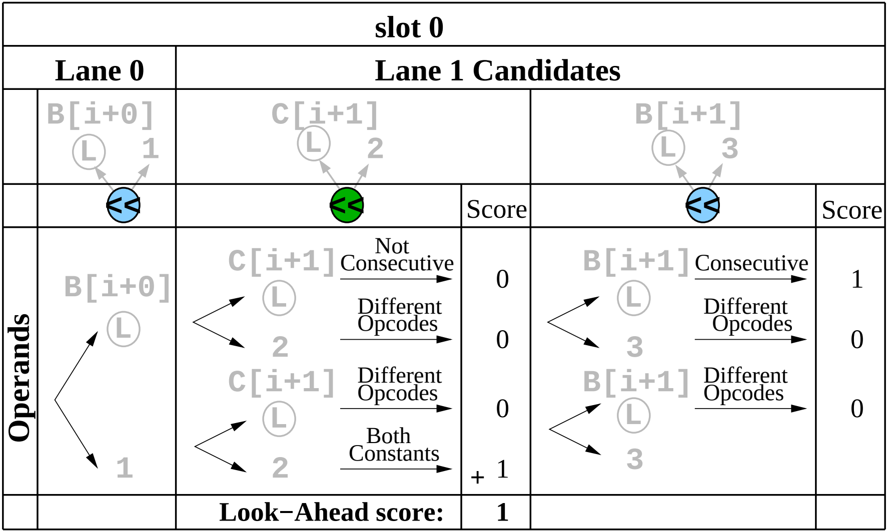

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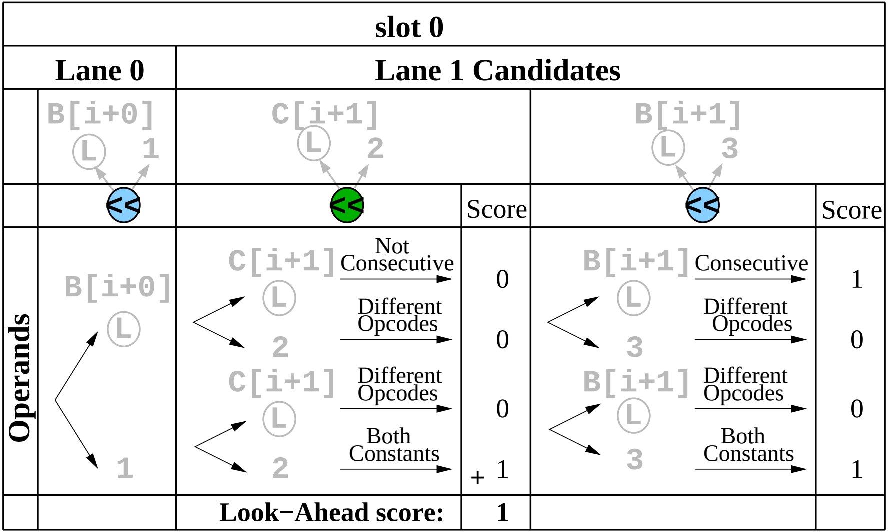

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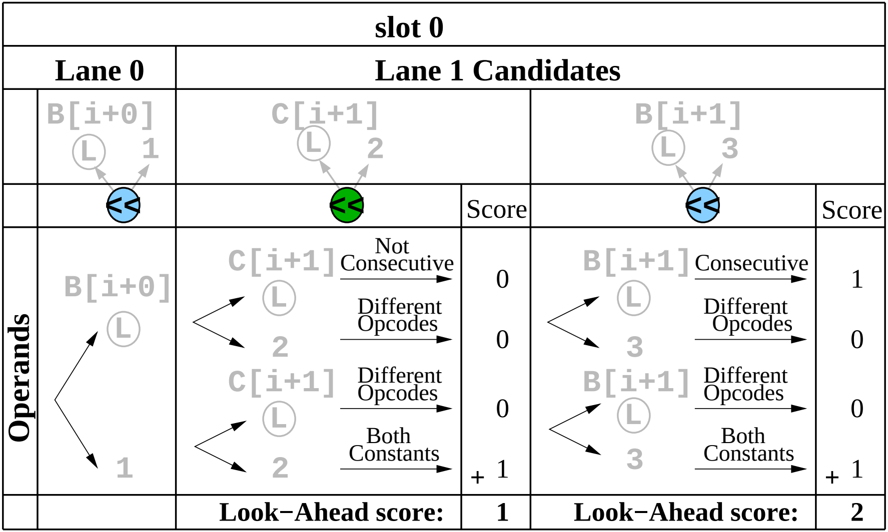

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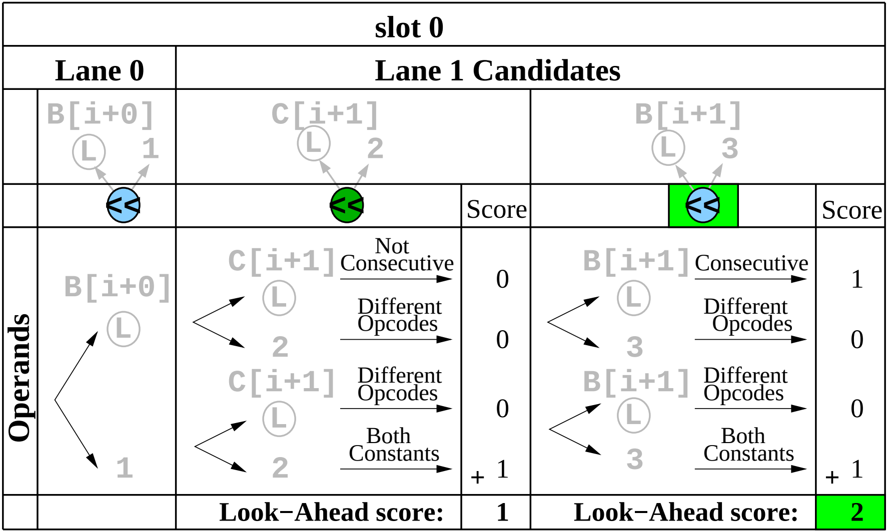

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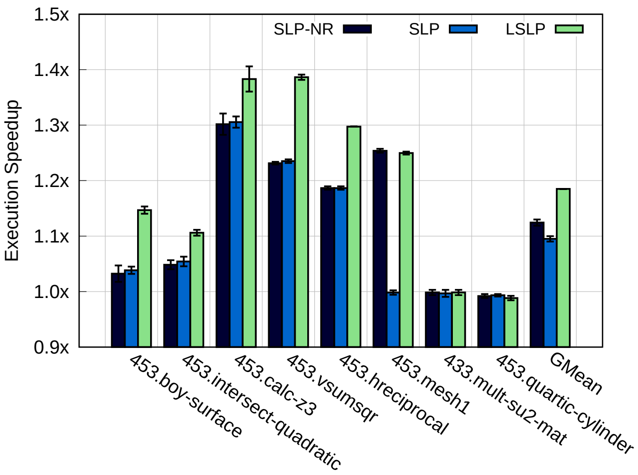
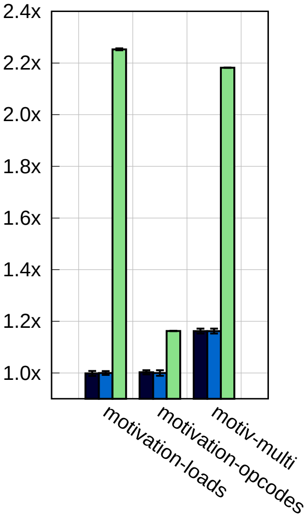
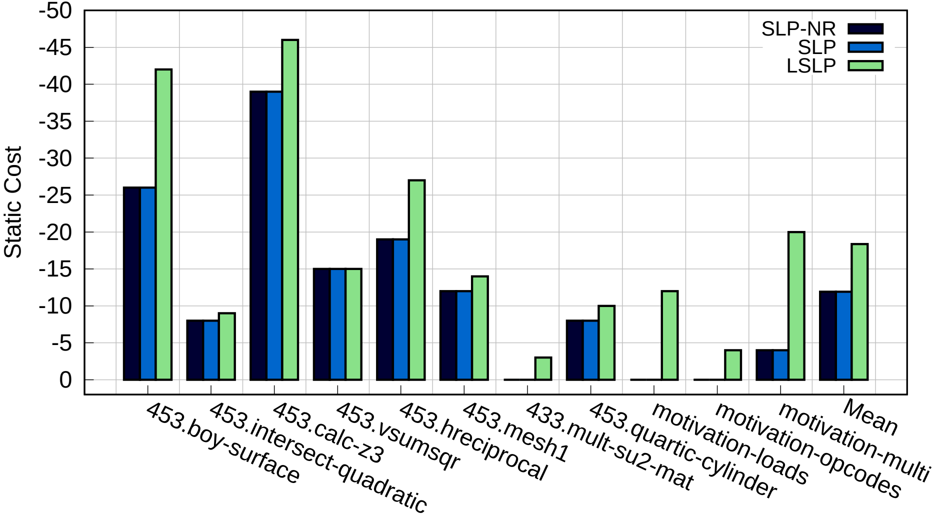
Performance (normalized to O3)



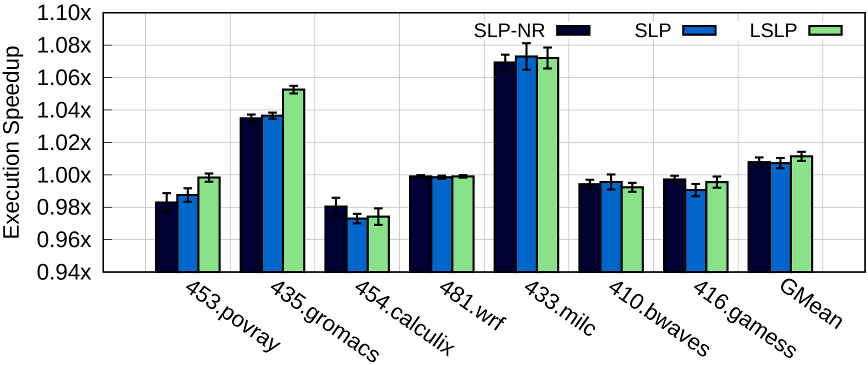


Static Cost (the higher the better)



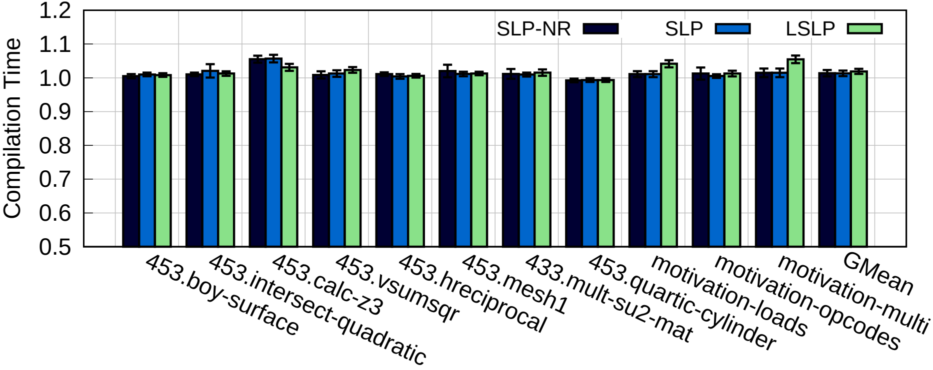
Performance (Full Benchmarks)

- About 1% speedup in 453.povray and 435.gromacs



Total Compilation Time

- No significant difference in compilation time



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