# A Relaxed Criterion for Loop Tiling

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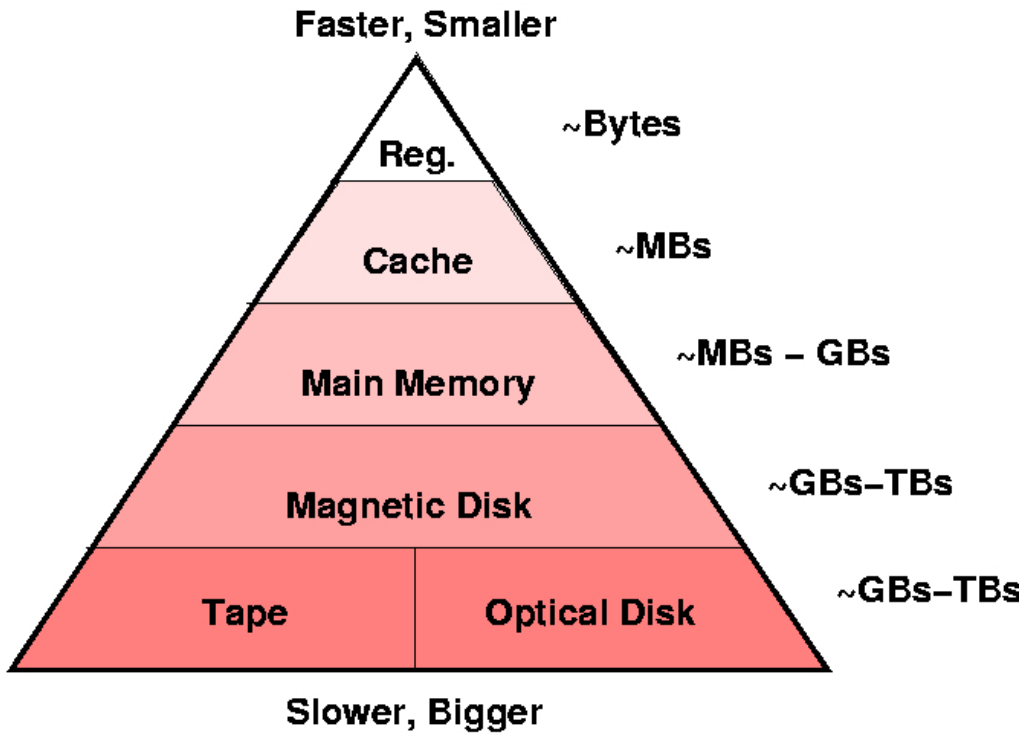
- Useful in architectures with a memory hierarchy



# Tiling Example

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    C[i][j] = A[j] + B[j];
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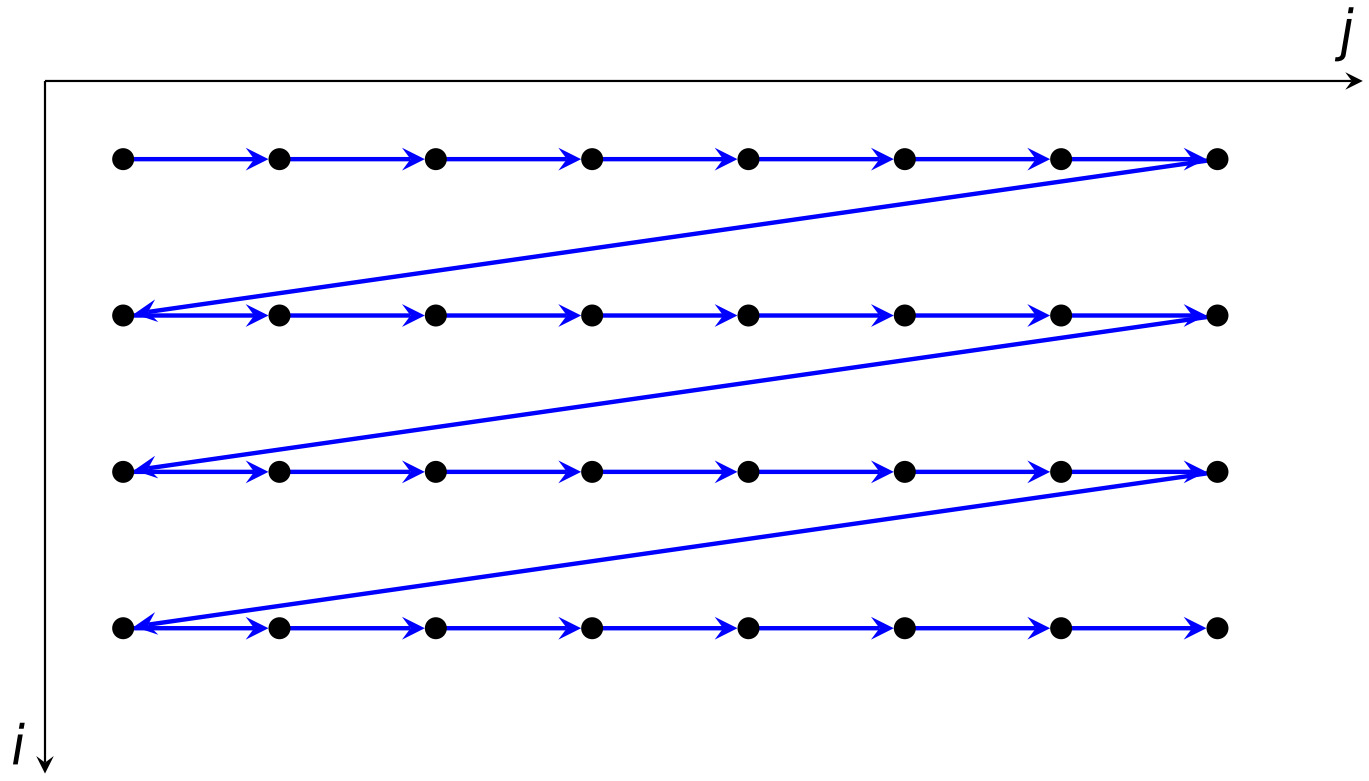


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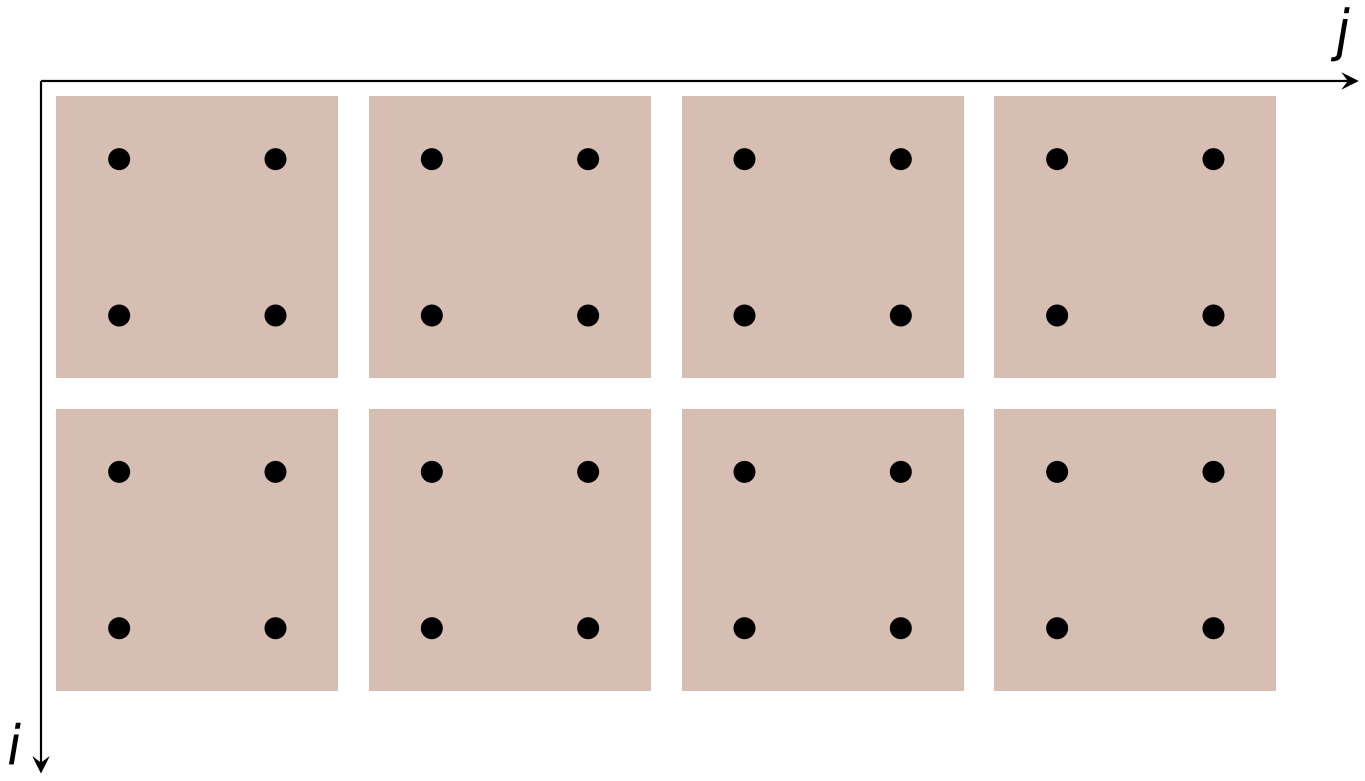


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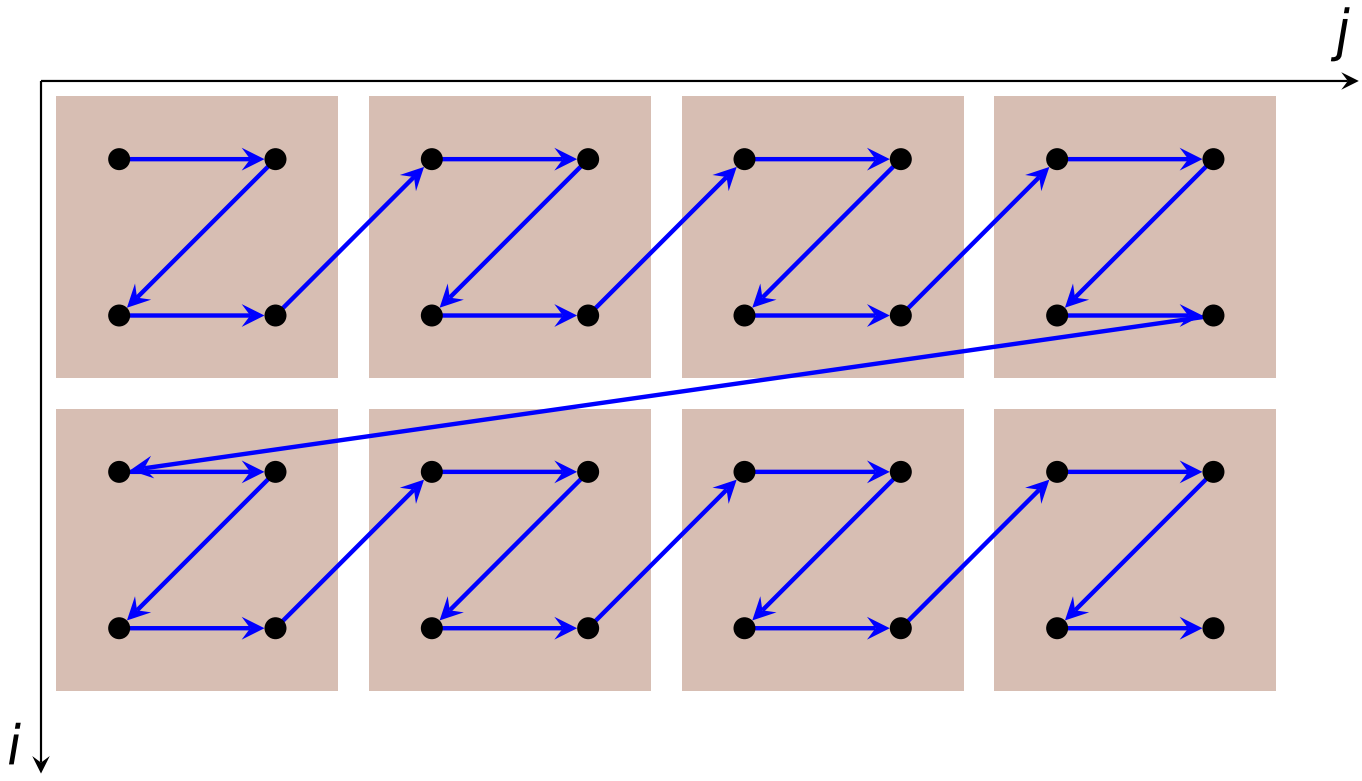


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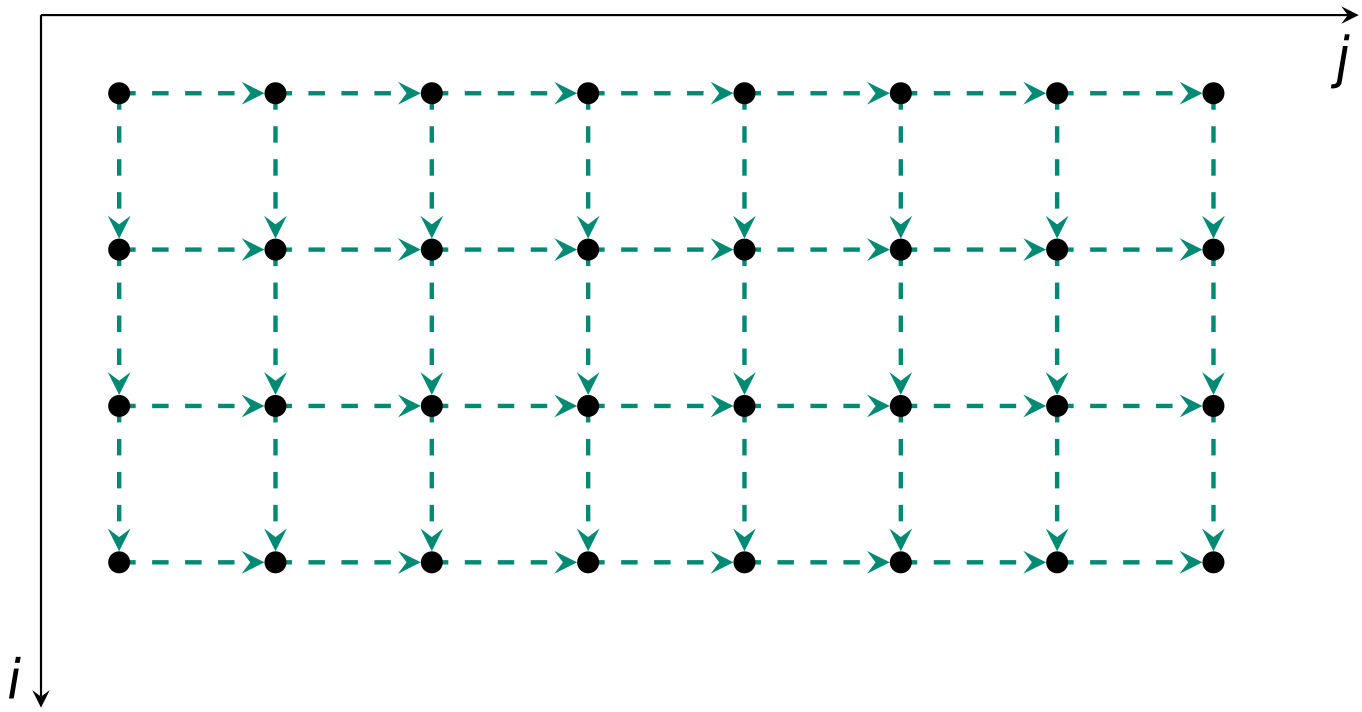
  - Each dependence is forward in each loop of the band
- A dependence is forward if it is oriented from earlier to later iterations

# Permutability Requirement Examples

A[i ][ j ] = f (A[i −1][j ], A[i ][ j −1]);

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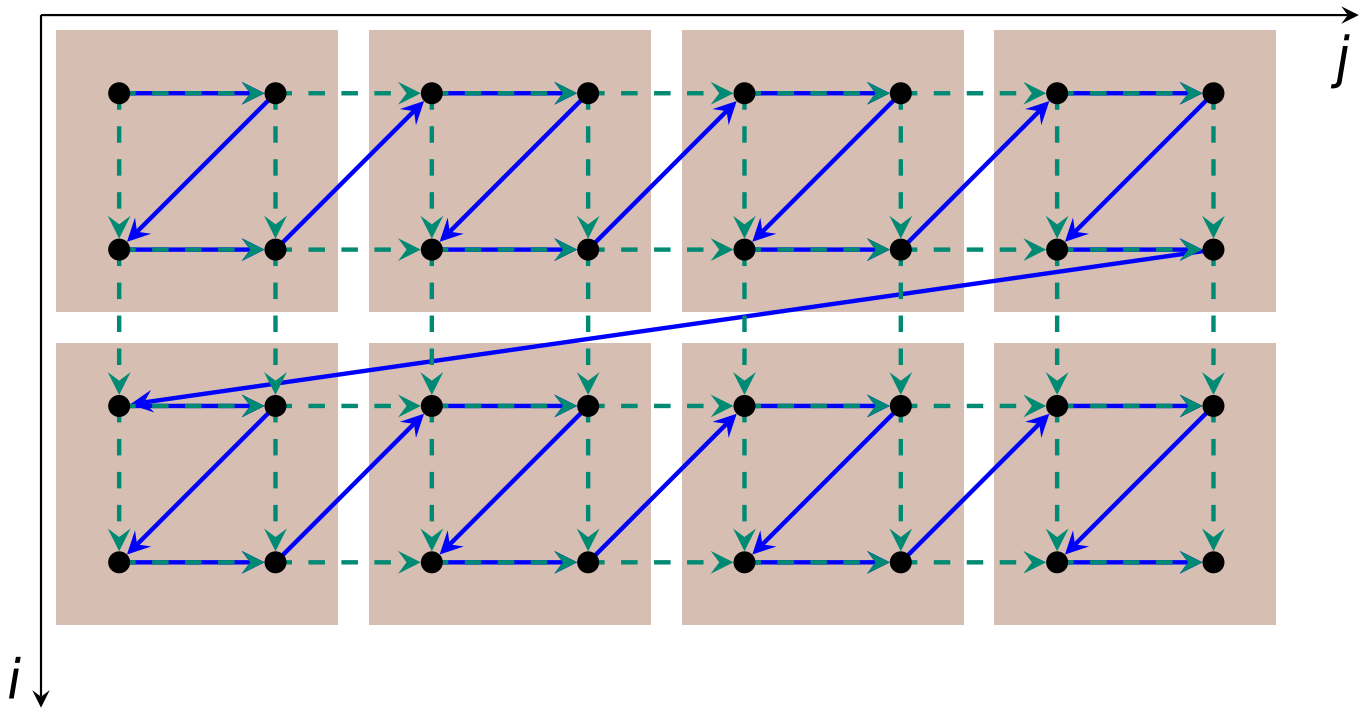


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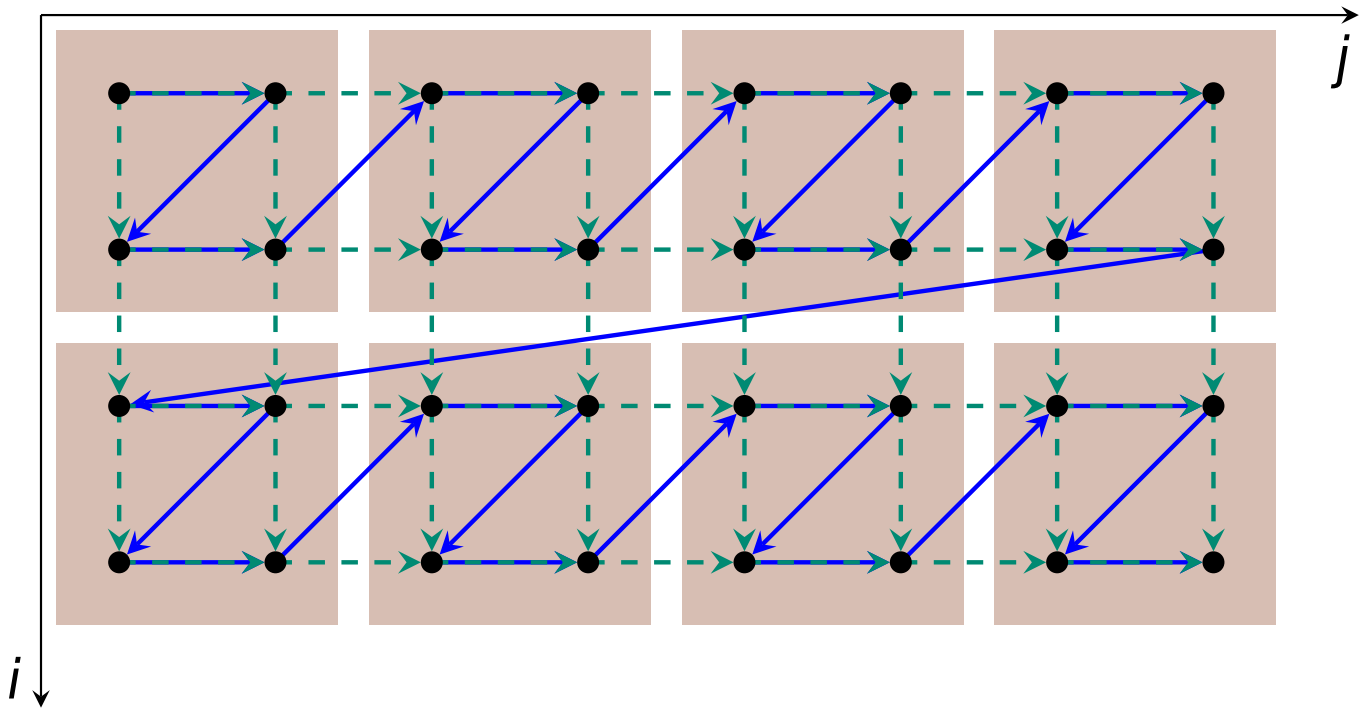


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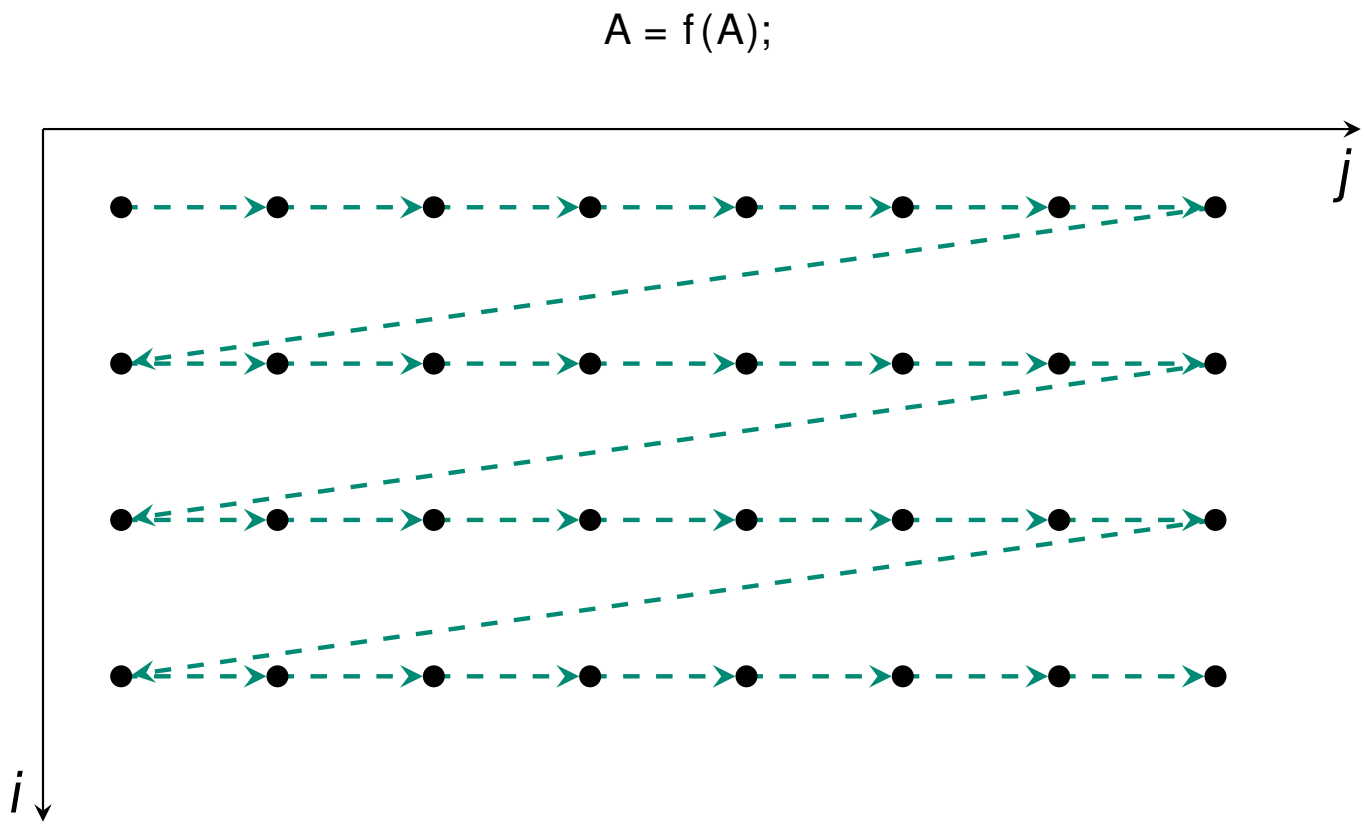


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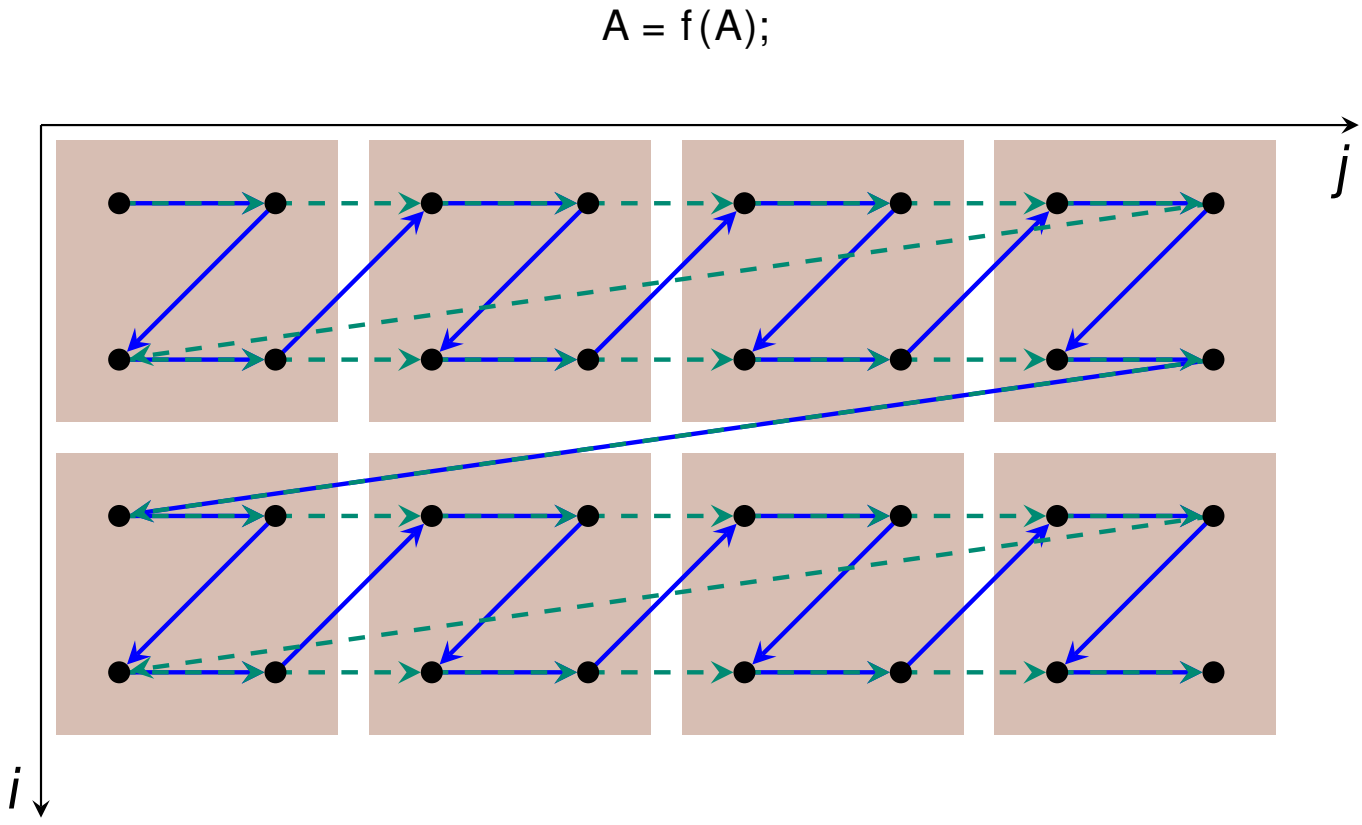


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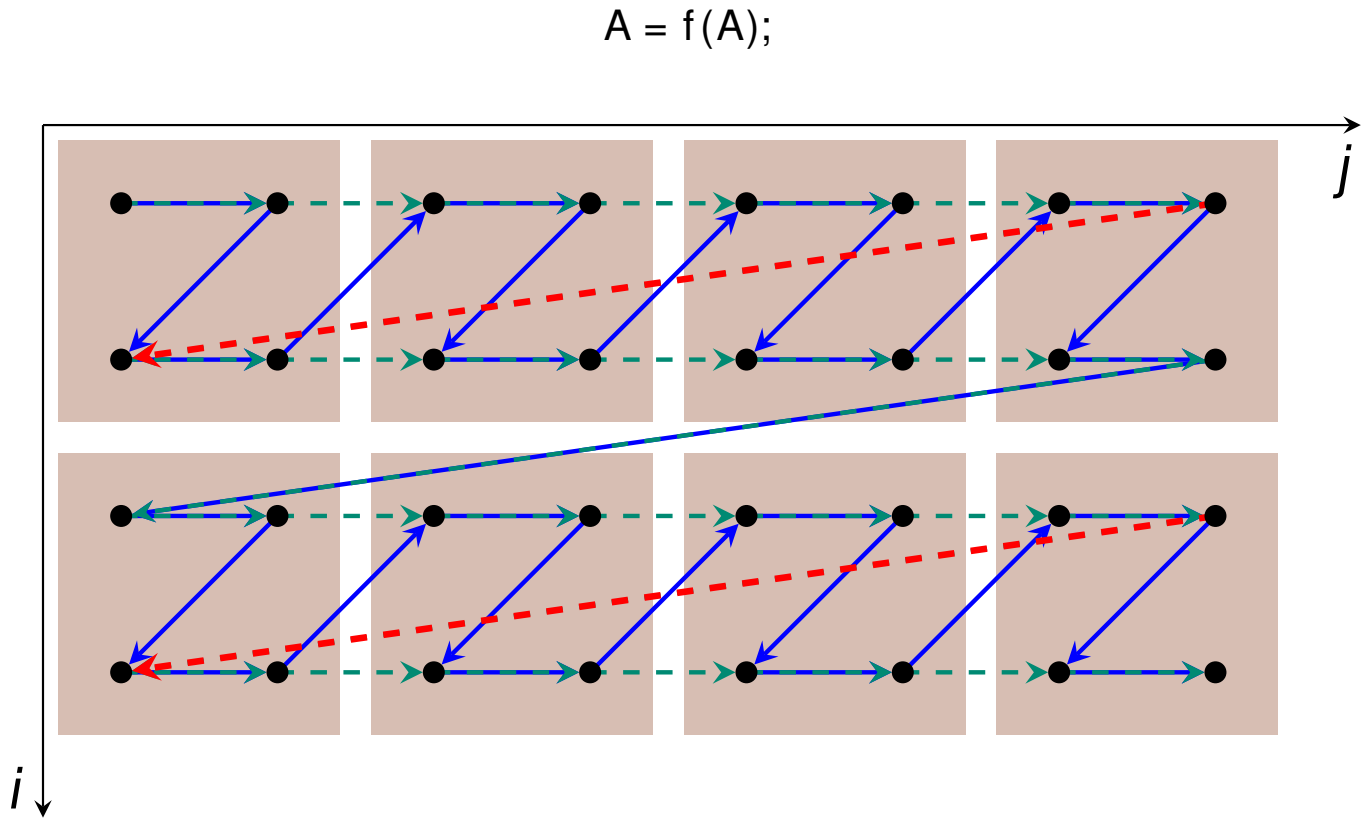


NOT OK

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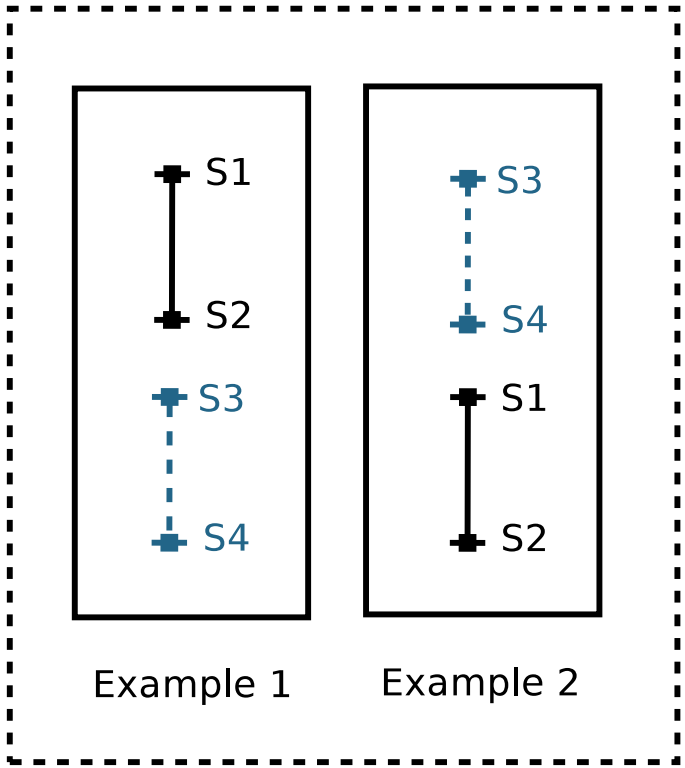
# Loop Transformation Legality

A loop transformation is correct if live ranges do not interfere after the transformation



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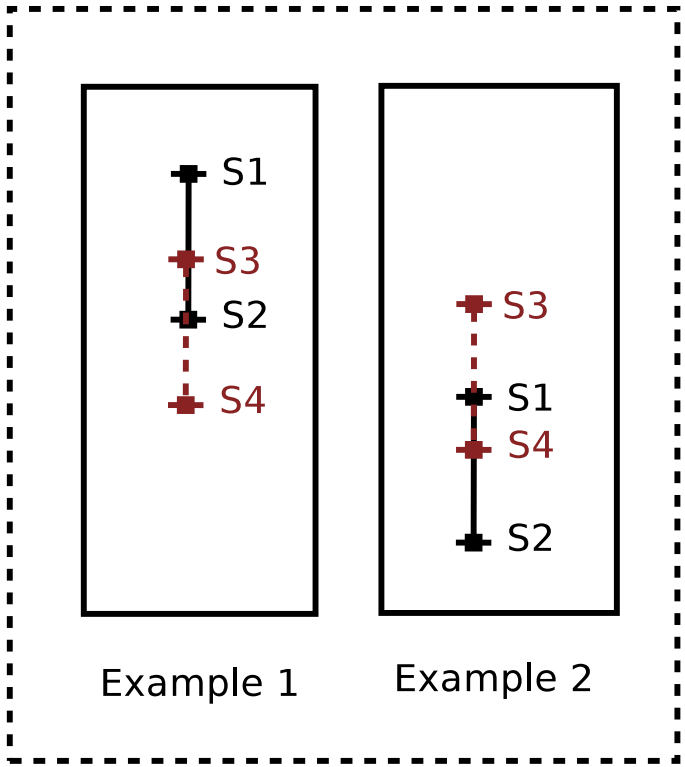

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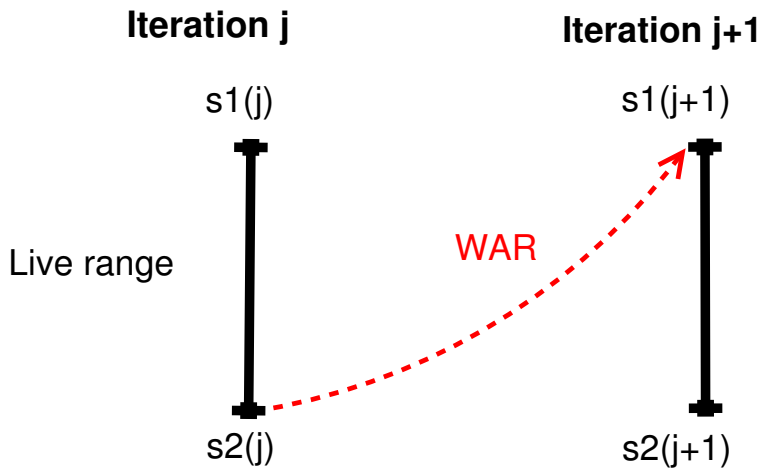

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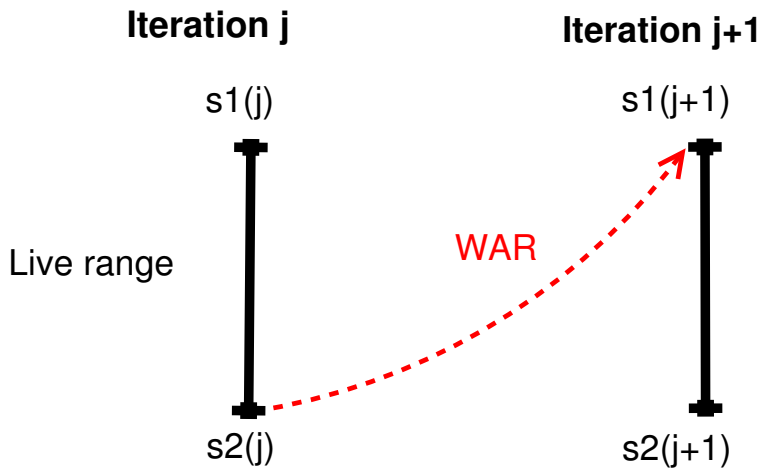


- Dependences adjacent to live ranges

# False Dependences prevent Tiling

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  for (i = 0; i < n; i++)
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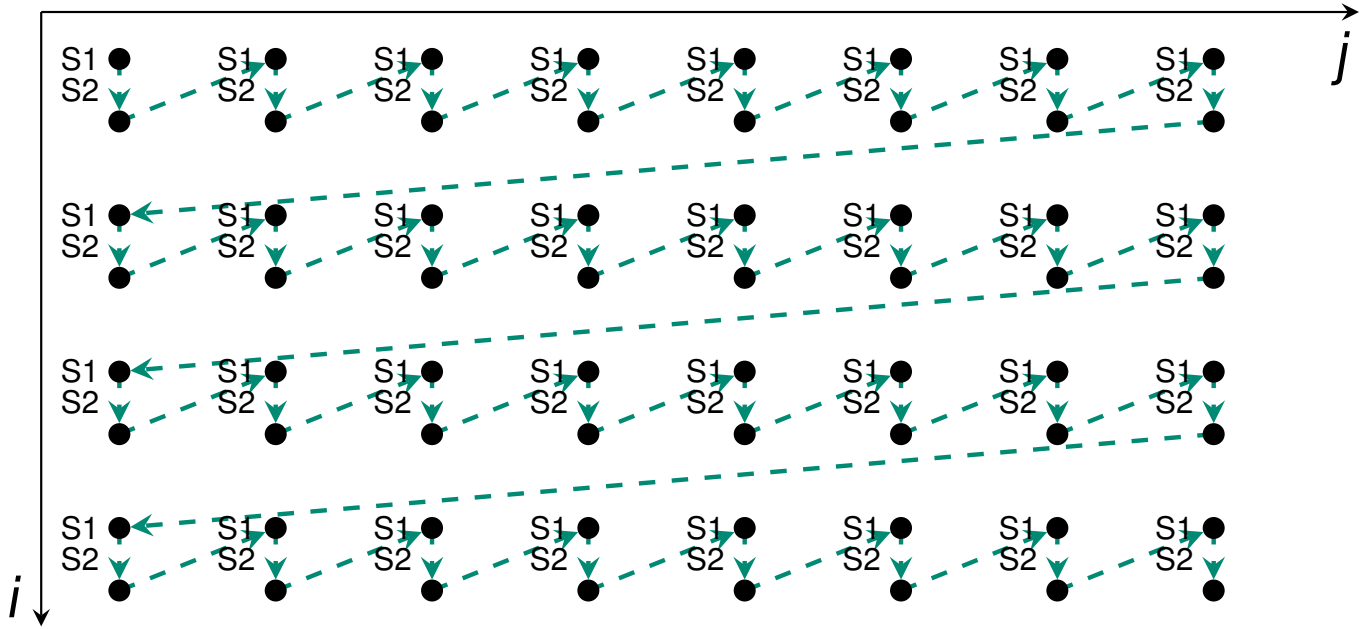

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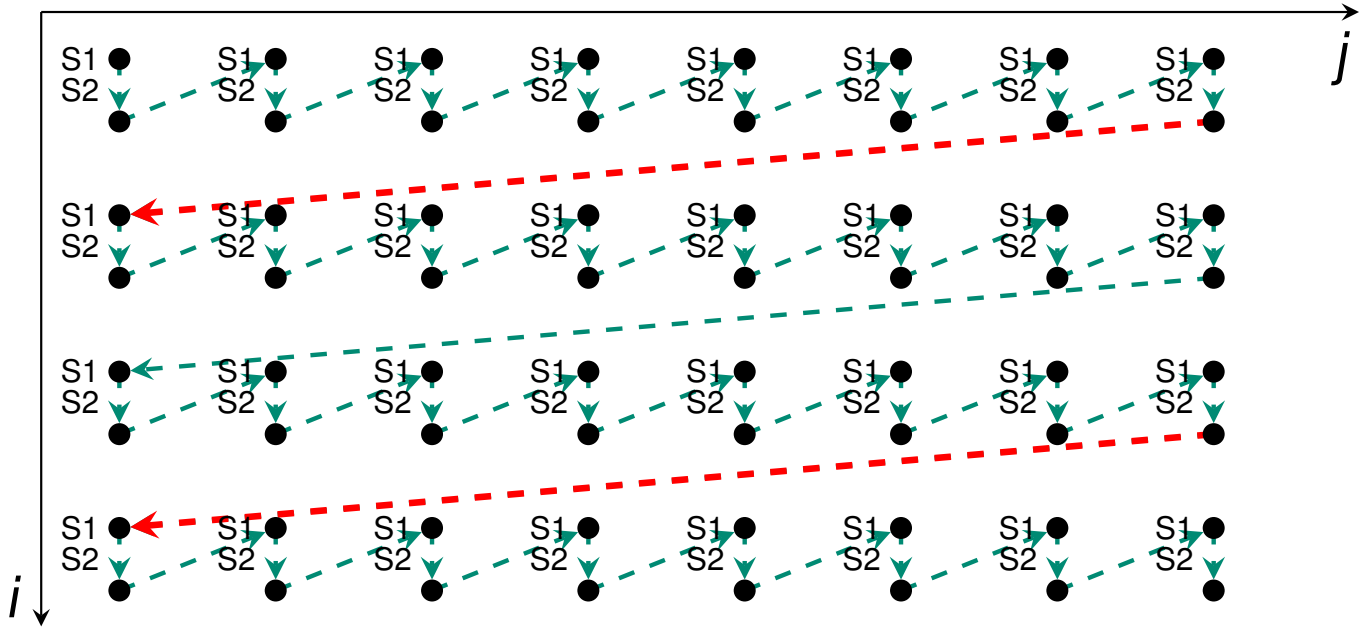


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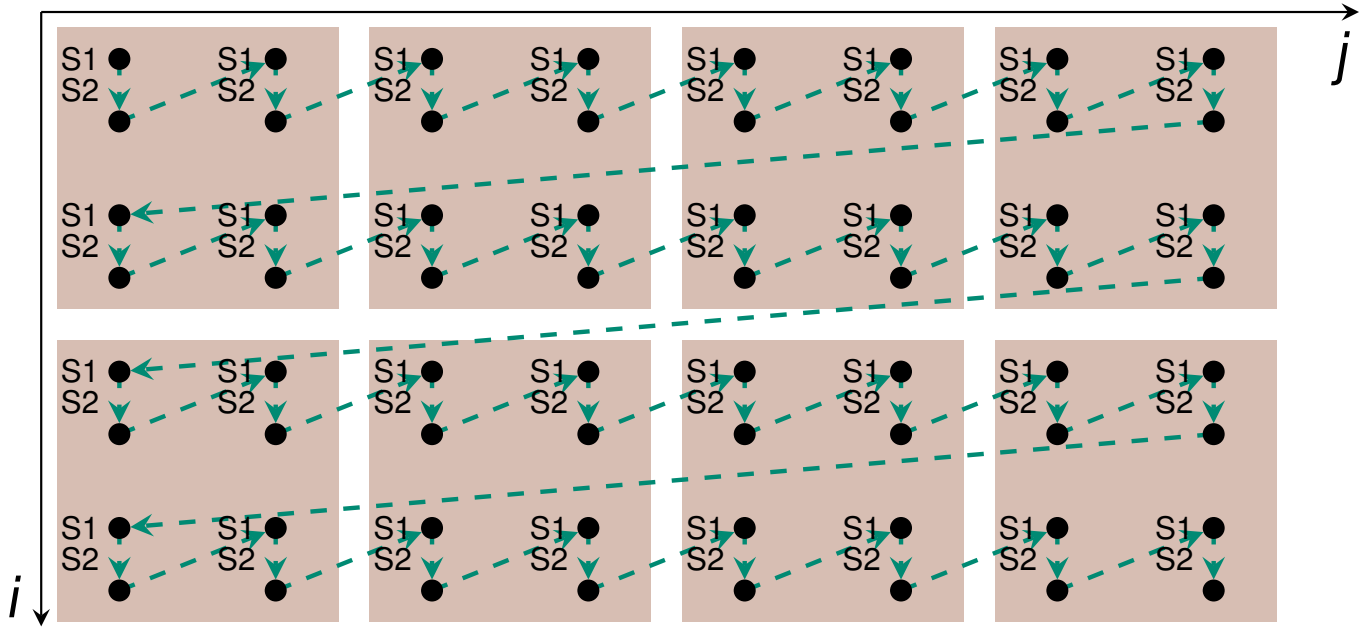


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- tiling only changes the order of execution of iterations
- if live ranges are local to an iteration then they are guaranteed not to interfer due to tiling

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- Relaxed Permutability Criterion
  - The same classical criterion except that we ignore anti-dependences that are adjacent to only *local* live ranges

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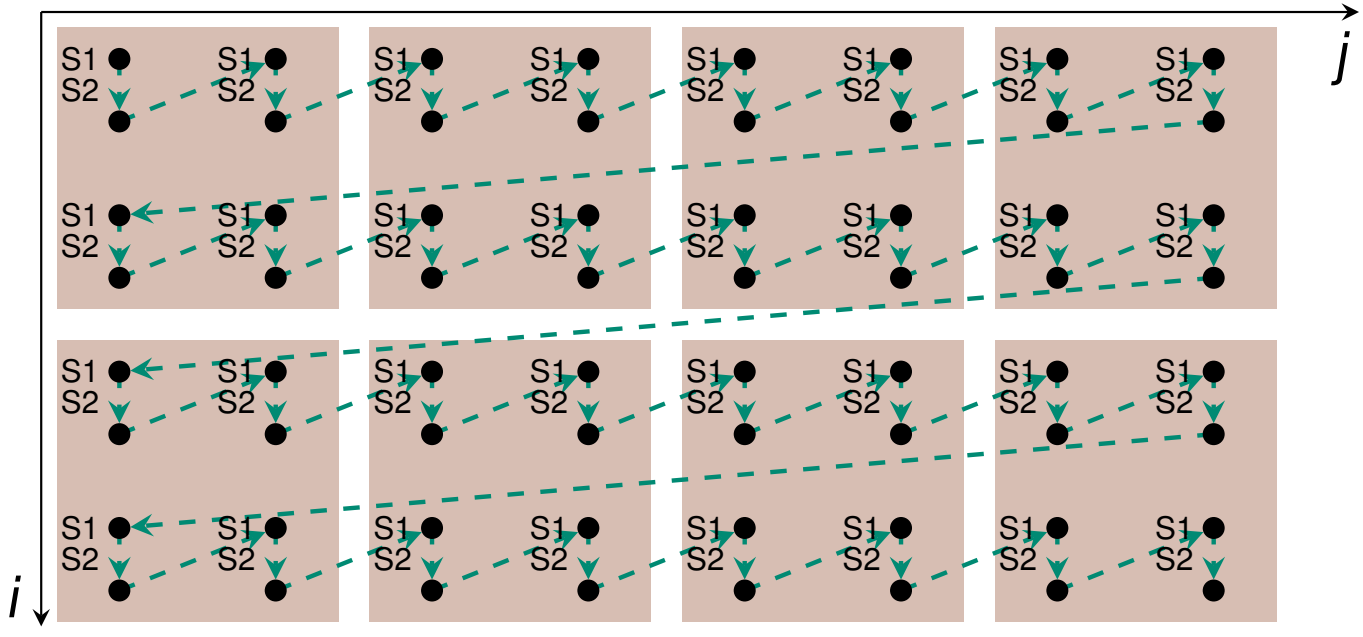


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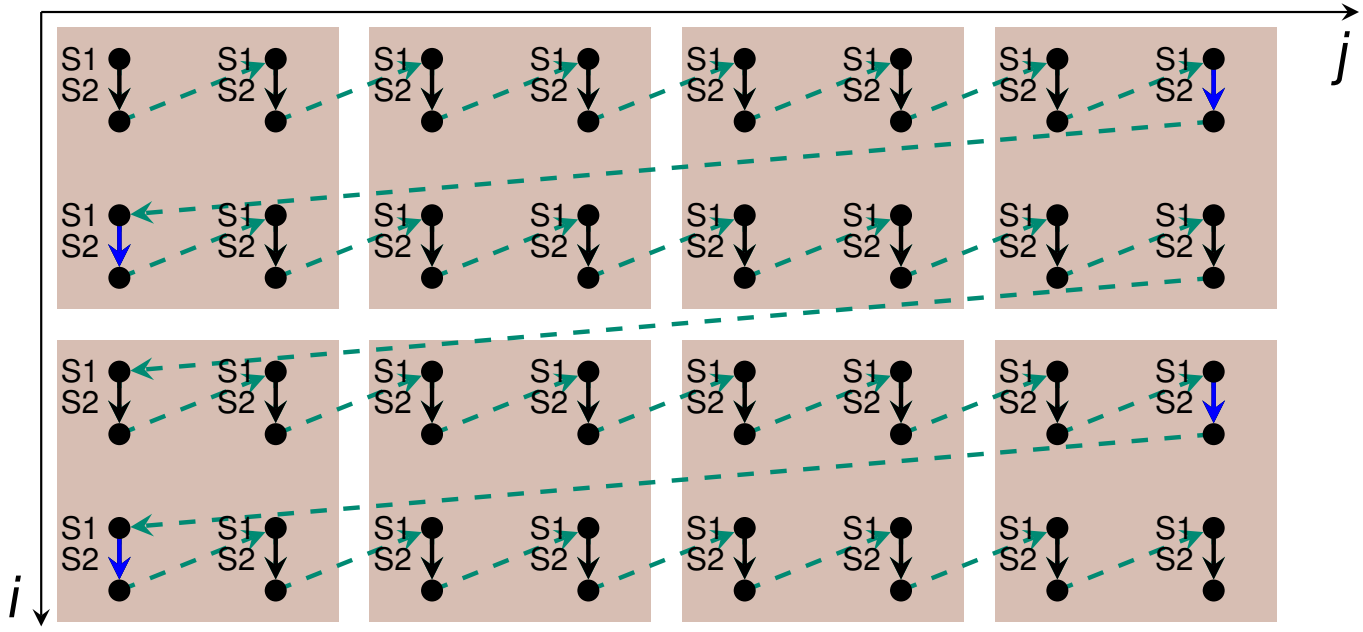


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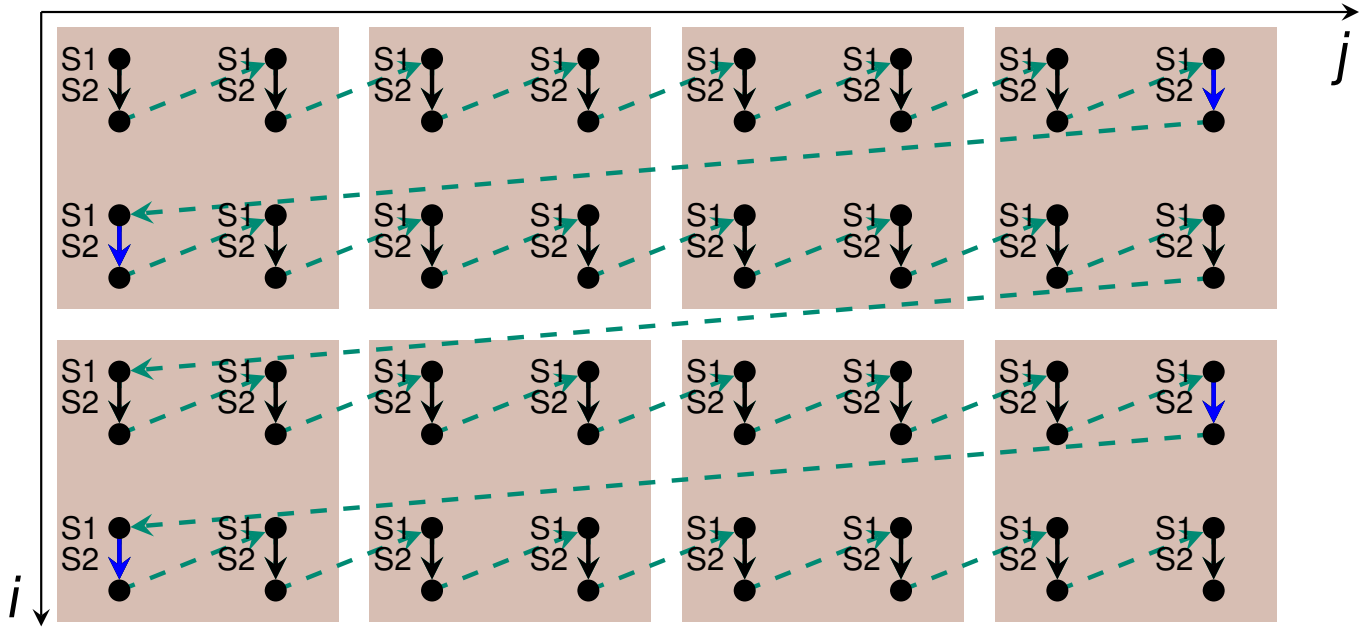


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Relaxed tiling criterion: allowed

# Tilability of Selected PolyBench Benchmarks

| | Original | 3AC | 3AC + relaxed criterion | Expanded |
|---|---|---|---|---|
| 3mm | yes | no | yes | yes |
| dynprog | yes | no | yes | yes |
| fdtd-2d | yes | no | yes | yes |
| syr2k | yes | no | yes | yes |
| fdtd-apml | yes | no | yes | yes |
| bicg | yes | no | yes | yes |
| symm | no | no | yes | yes |
| cholesky | no | no | yes | yes |

# Conclusion

Relaxed permutability criterion

- Allows tiling in presence of false dependences
- No expansion or privatization required

Future directions

- Combination with on-demand array expansion

# Outline

Relaxed Permutability Criterion

Conclusion

PENCIL

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**PENCIL**

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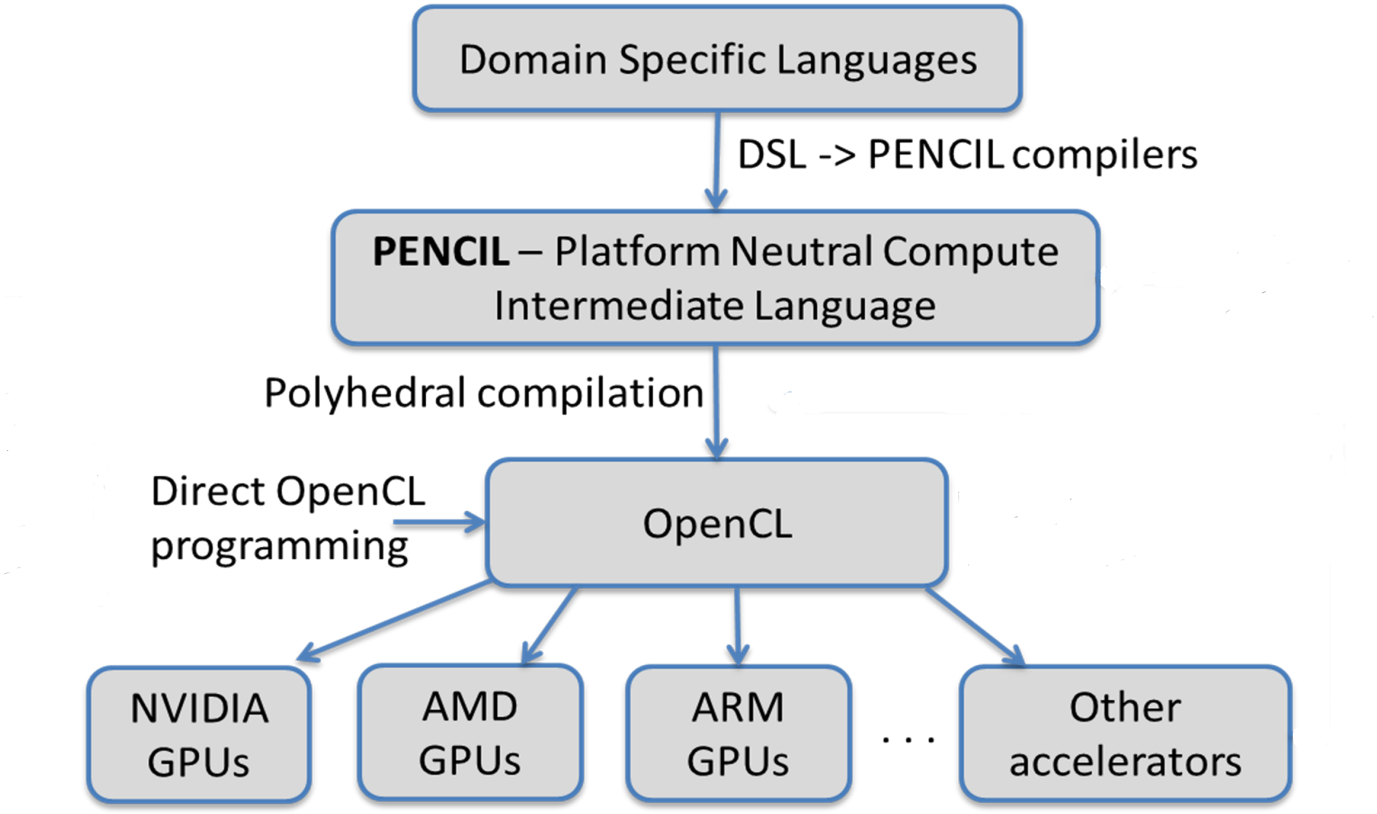
- Solution
  - Write code in a high level language
  - Use a compiler for parallelization/optimization

# PENCIL


Domain Specific Languages
DSL -> PENCIL compilers
PENCIL – Platform Neutral Compute Intermediate Language
Polyhedral compilation
Direct OpenCL programming
OpenCL
NVIDIA GPUs
AMD GPUs
ARM GPUs
. . .
Other accelerators

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    - cannot read or write to a pointer except passing an array reference to a function: `foo(A);`
- no gotos

Extensions (builtins and directives)

- `__pencil_assume(expression)`
- `__pencil_kill(T)`
- `__pencil_reduce(...)`
- `#pragma pencil independent`
- Summary functions

# Compiling PENCIL

- We use the PPCG polyhedral compiler
- Polyhedral moldel: an algebraic representation of programs (focus on loop nests).
- Static-affine control
  - Static control: not data dependent (`if (A[i])`).
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  - Treated as a *may* access to the whole array dimension
  - Example:

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- Non static-affine conditionals

```
if (A[i])
{
. .  B[i] = 0;
. .  C[i] = 0;
}
```

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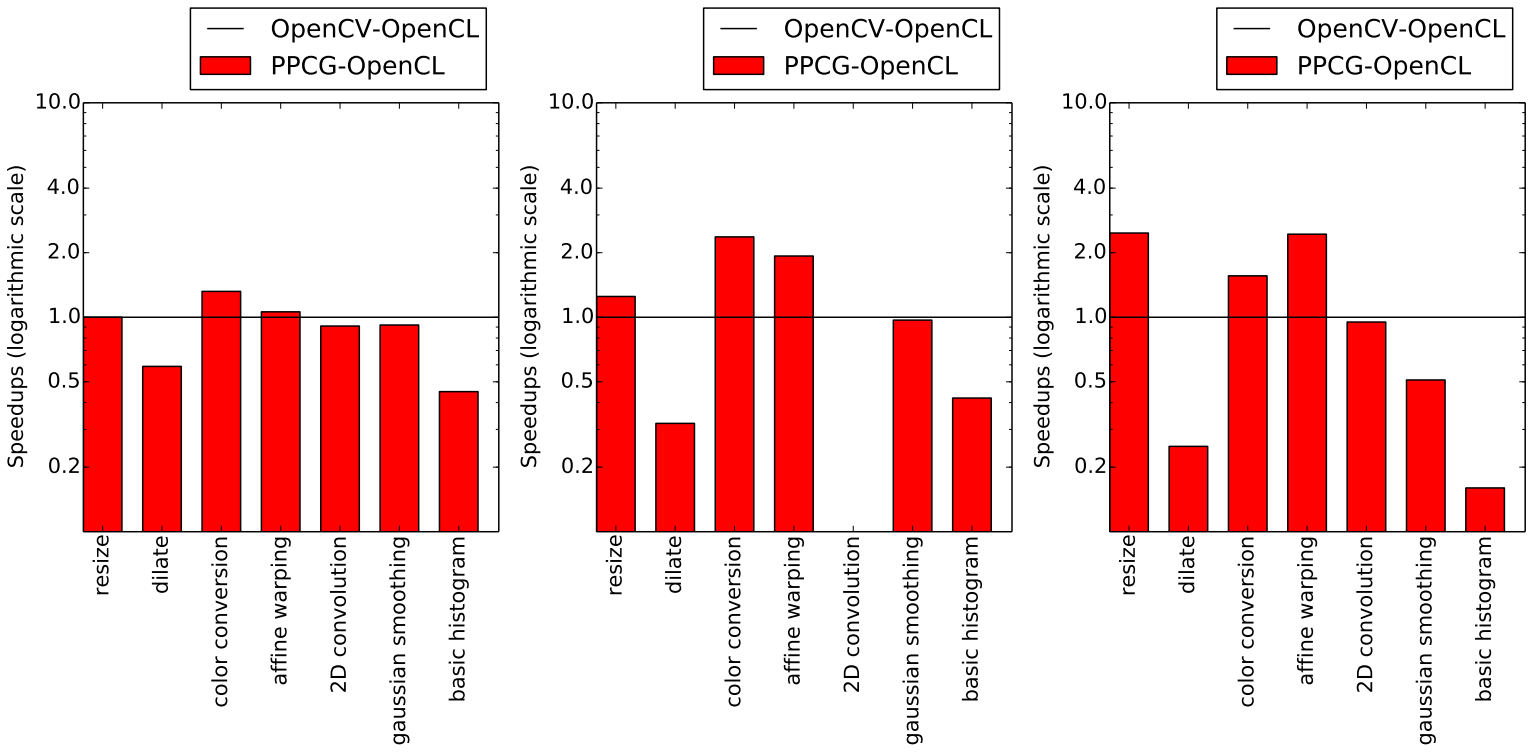
- **independent** directive
  - Used currently during parallelism detection (remove loop carried dependences)

# Image Processing: Experiments

Speedup of code generated from PENCIL over OpenCV library




Nvidia Fermi ARM Mali AMD Radeon