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Optimization Through Recomputation in the Polyhedral Model

By Mike Jongen,
Luc Waeijen,
Roel Jordans,
Lech Jóźwiak,
Henk Corporaal.

Contents

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Introduction

Introduction

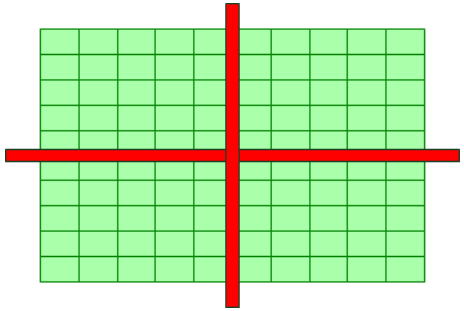
- (Mobile) systems use more artificial neural networks
  - Artificial vision
  - Image processing
  - Speech recognition

- Large amount of data accesses

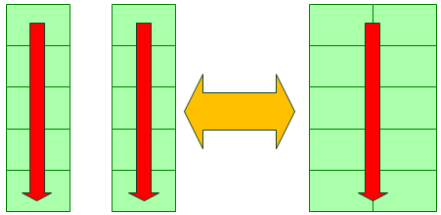
- Can be improved by code transformations

Current possibilities and extensions

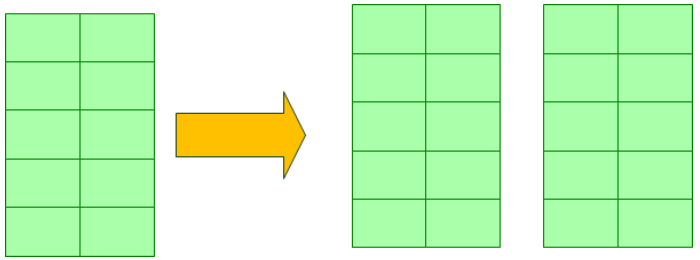
- Tiling



- Fusion
- Distribution



- Recomputation/overlapped tiling
  - Allows for better paralellism
  - Reduces memory traffic



This paper

- An example CNN application which includes recompute
- Extension of Polly
- Demonstration of the effectiveness of recomputation

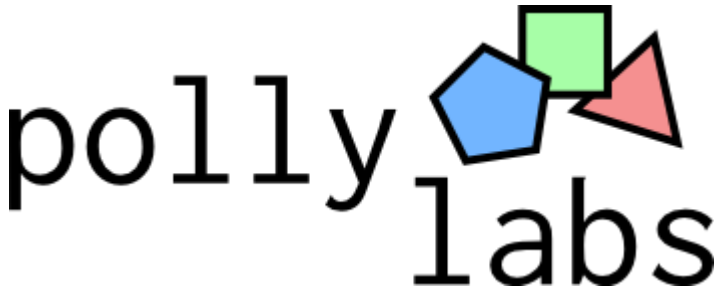
Related Work

Automated polyhedral optimization frameworks

- Greatly reduce the effort of translating the original network description into an optimized form
- Automatically verifying the validity
- Different options: Polly, R-Stream-TF, and PPCG
- None of these frameworks provides a method of including recomputation in the optimization space

Why do we use Polly

- Uses the Polyhedral model for optimizations
- Direct integration with the LLVM compiler framework
- Adjustable
  - Add extra functionality
  - User defined schedules
  - Automate the process



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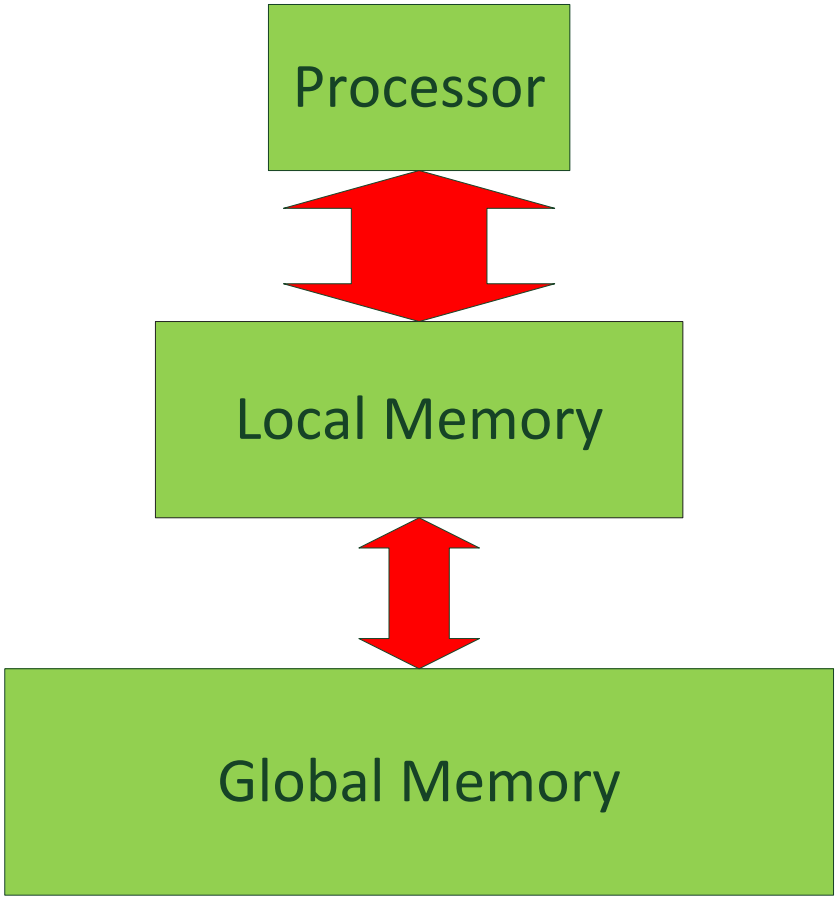
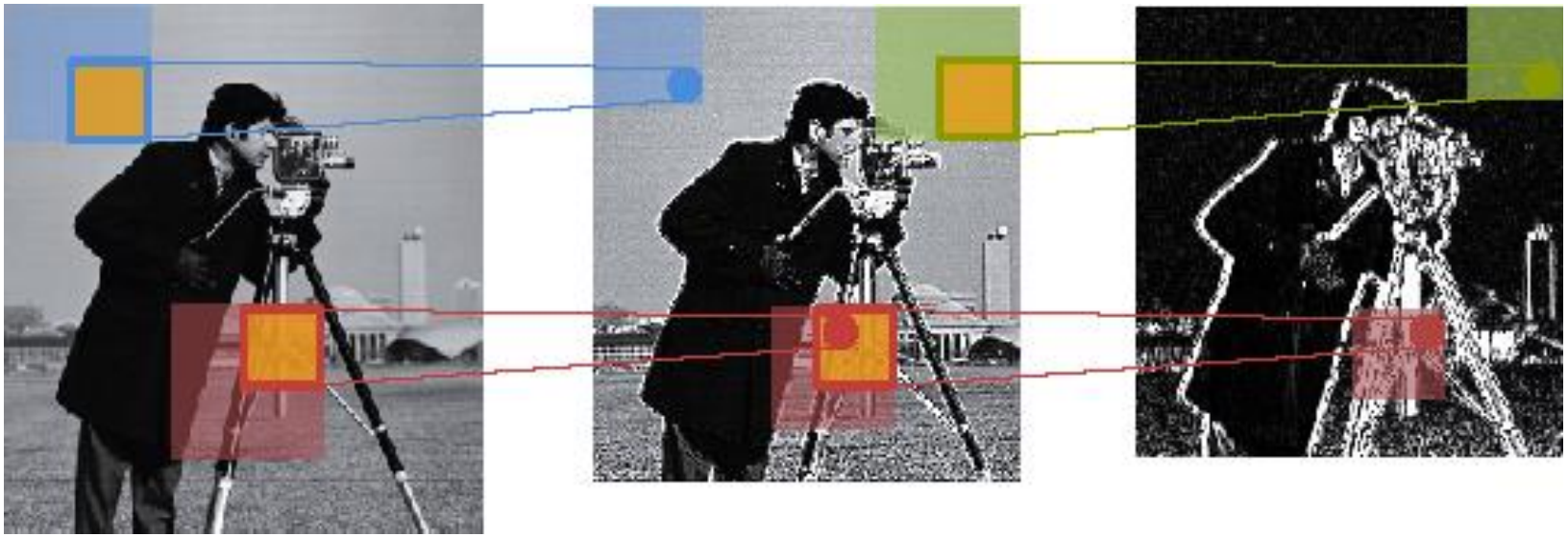
Optimizing Through Recompute

Where innovation starts

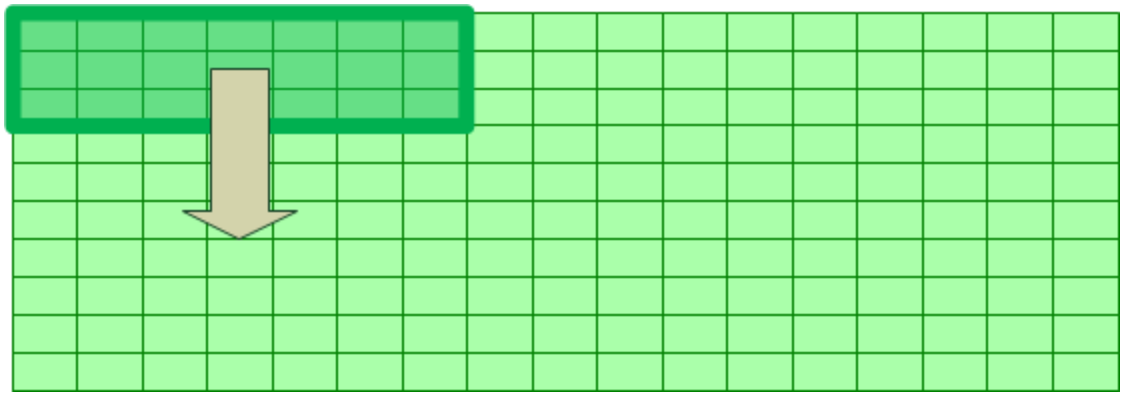
System Architecture



Educational Example



Inter Tile Reuse



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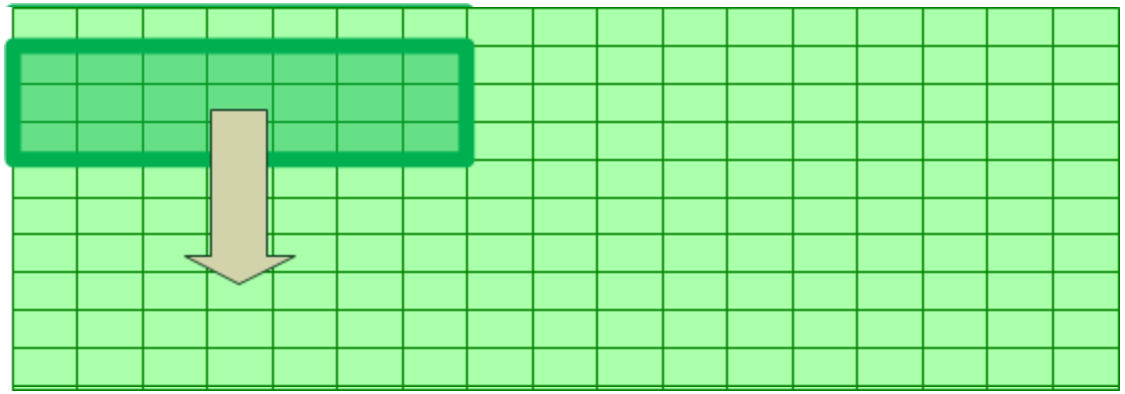

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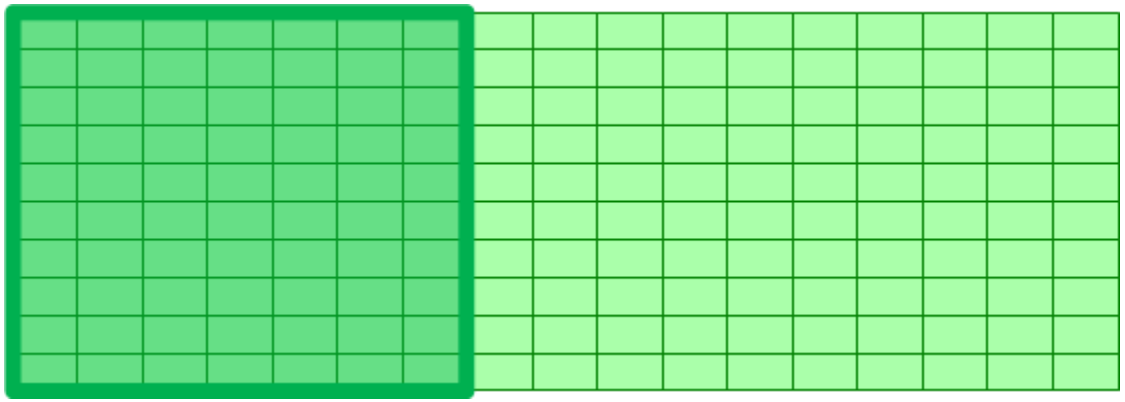

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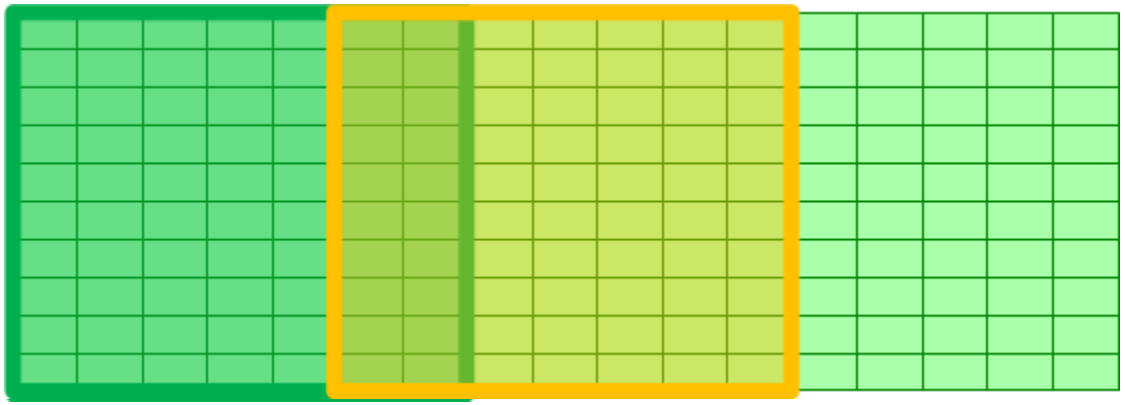
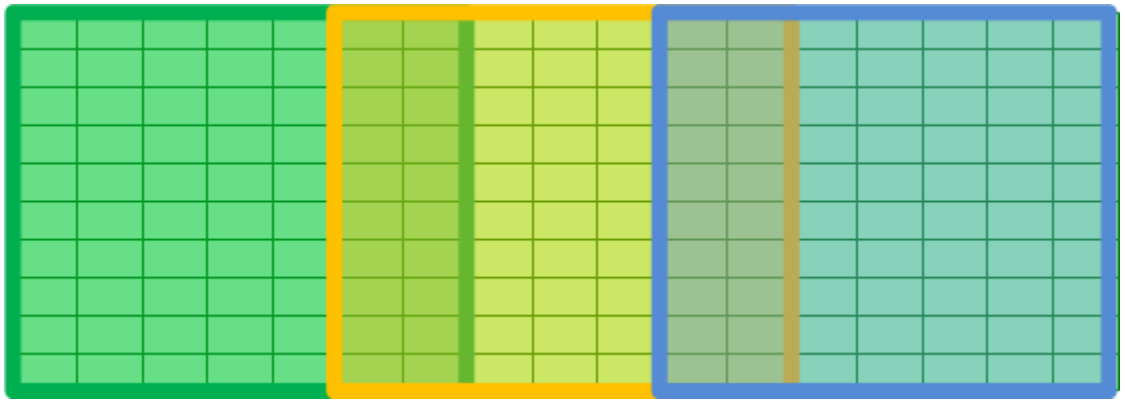


Other Dimensions



Methods to handle overlap

- Store the overlap globally
- Store the overlap locally
- Recompute the overlap

Global Method

- Pixels are stored externally
- Small buffer size
- Expensive memory accesses

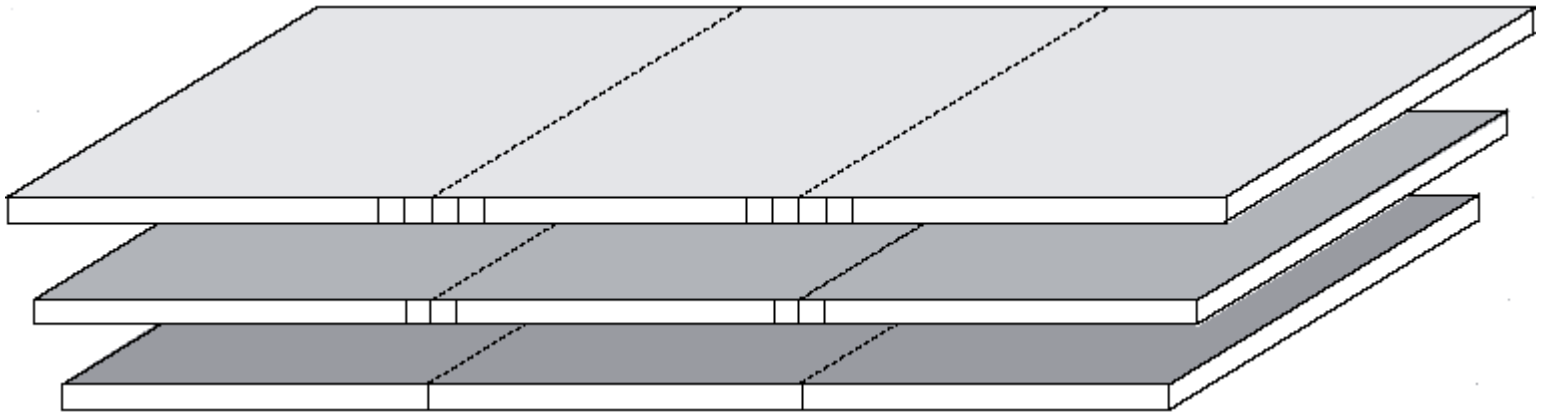
Local Method

- Pixels are stored locally
- Larger buffers required
- Cheaper accesses

Recomputation Method

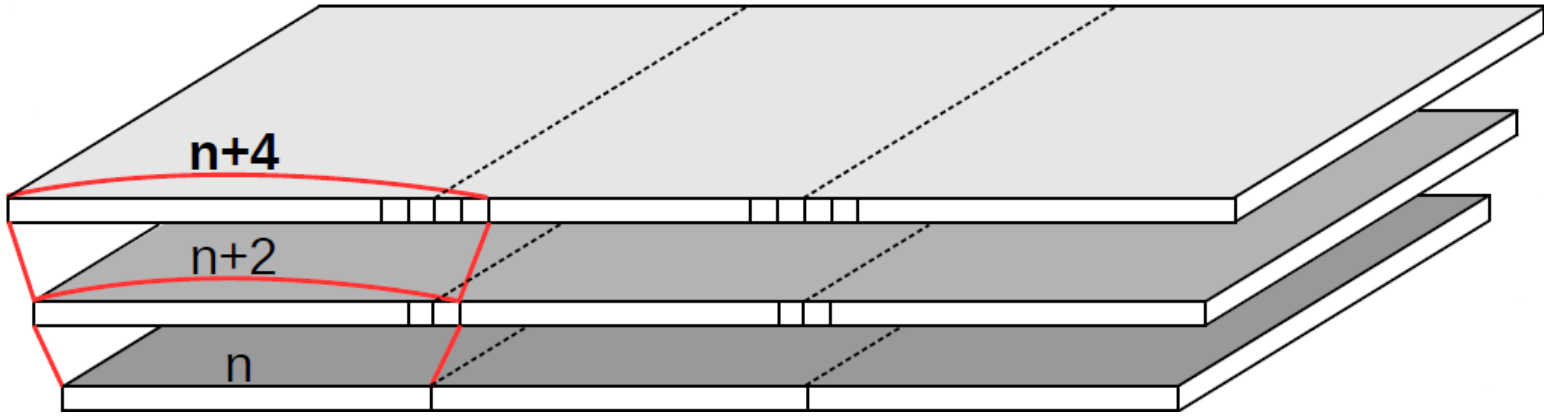
- Recomputes the pixels
- No extra memory required
- No extra accesses required
- More computations are required

Recomputation Tradeoffs



Recomputation Tradeoffs

Storing the overlap



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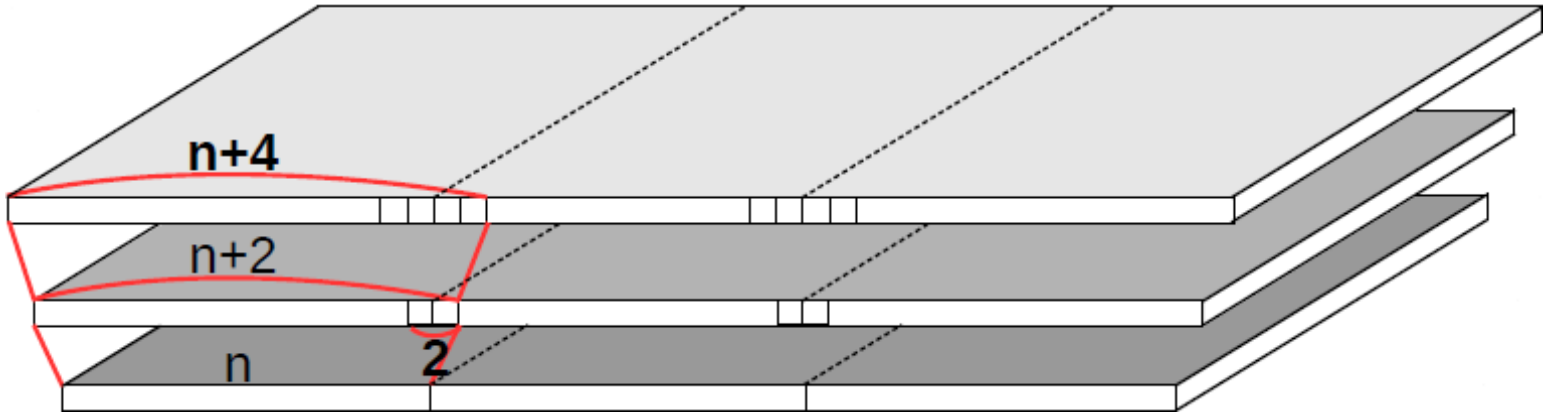

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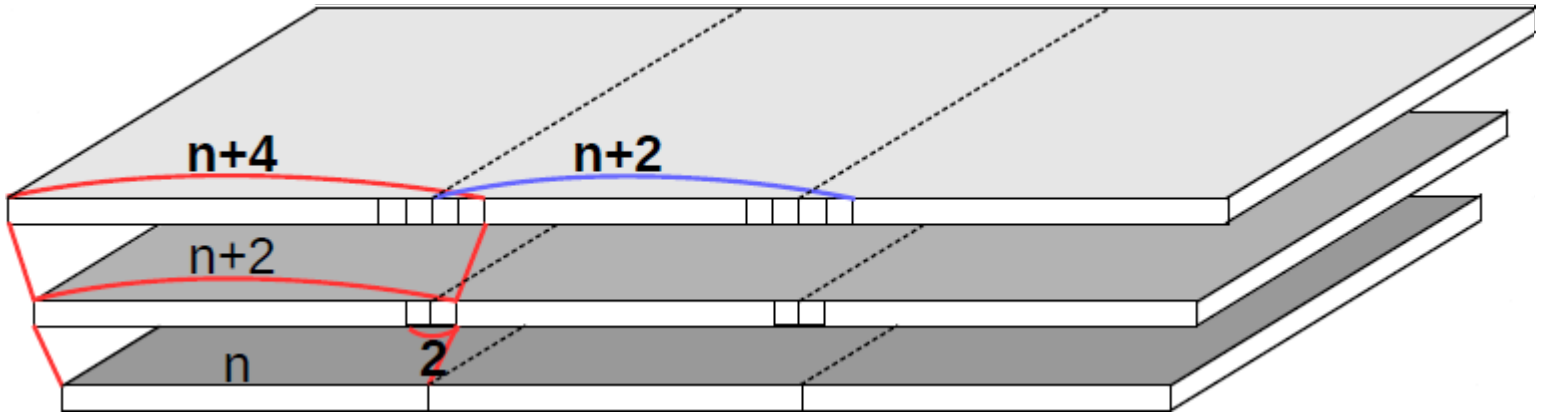

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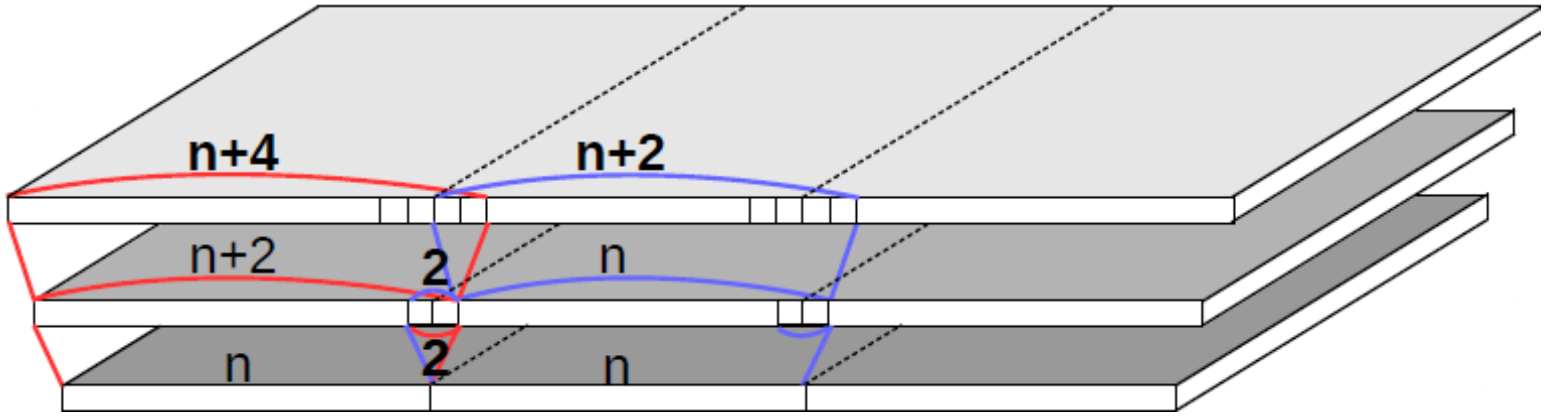

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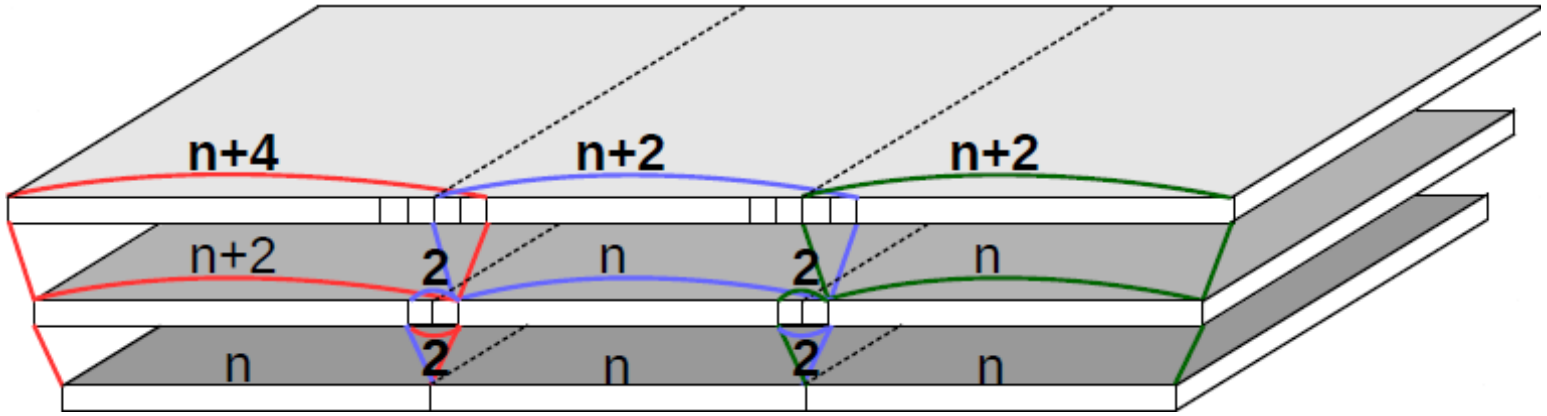
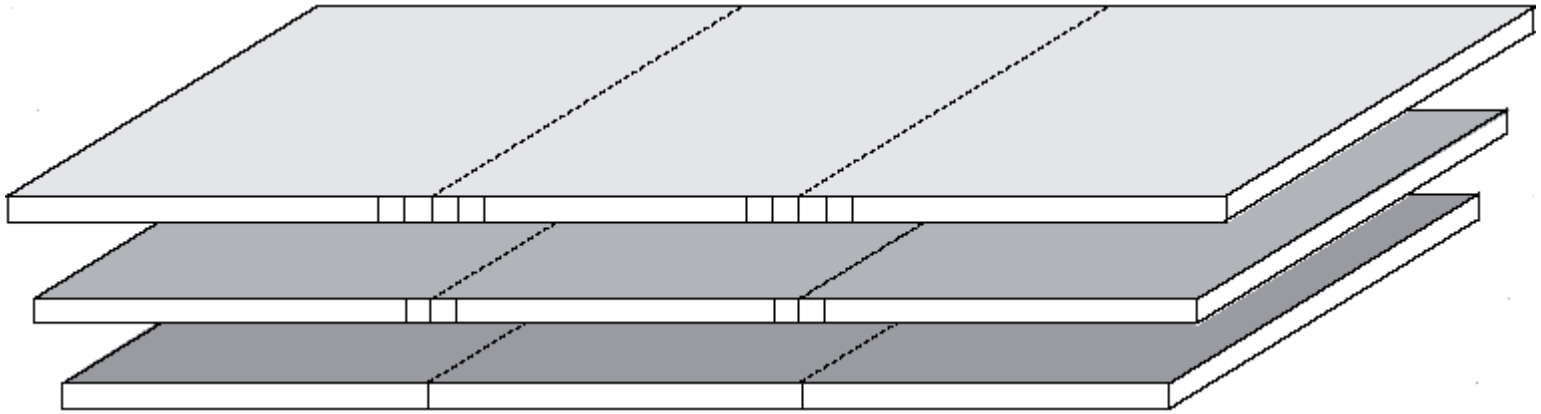


Recomputation Tradeoffs

Recomputing the overlap



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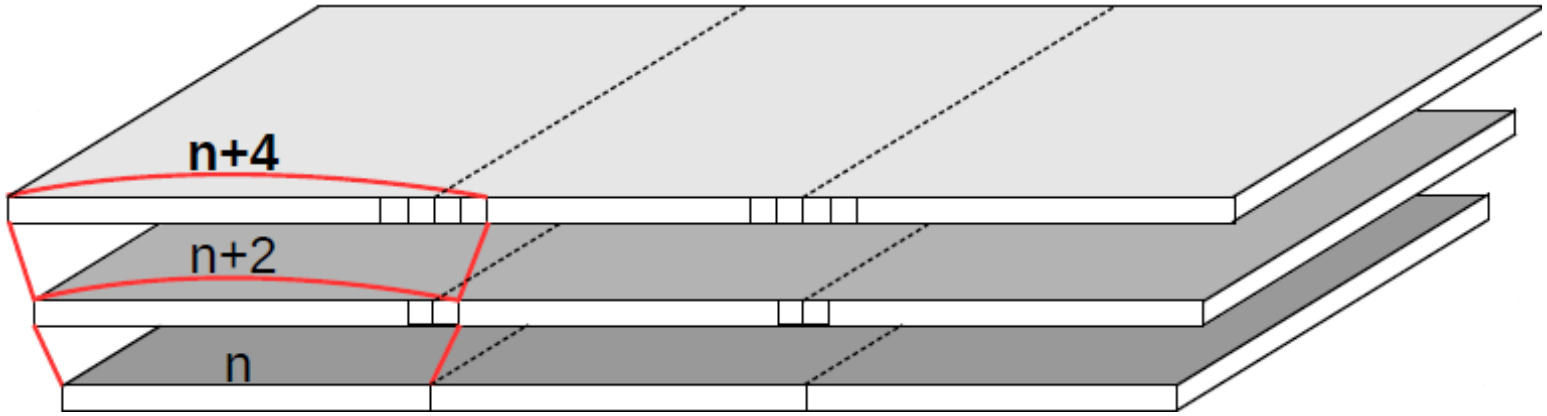

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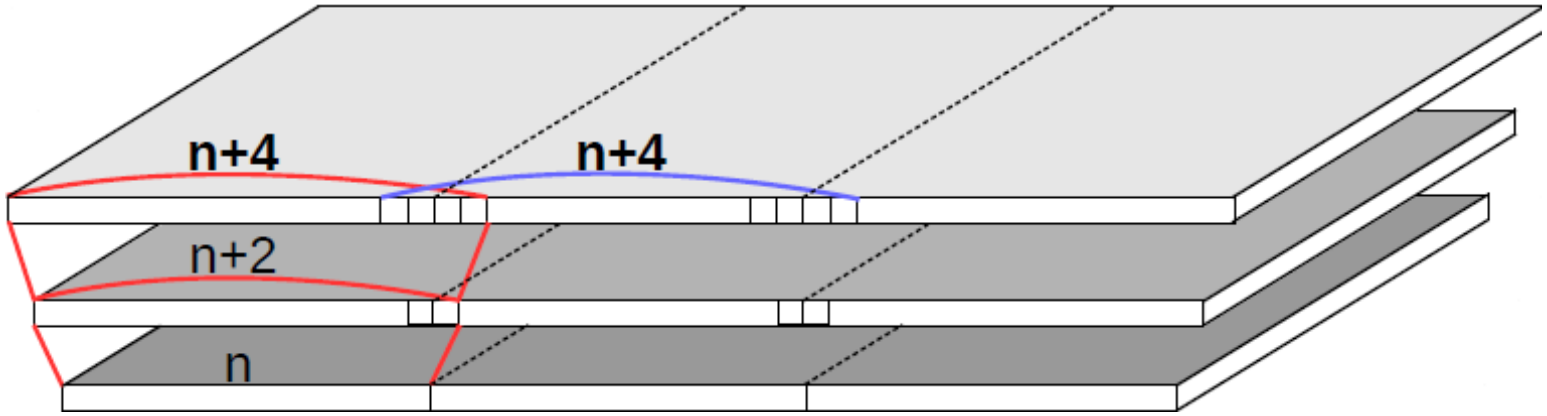

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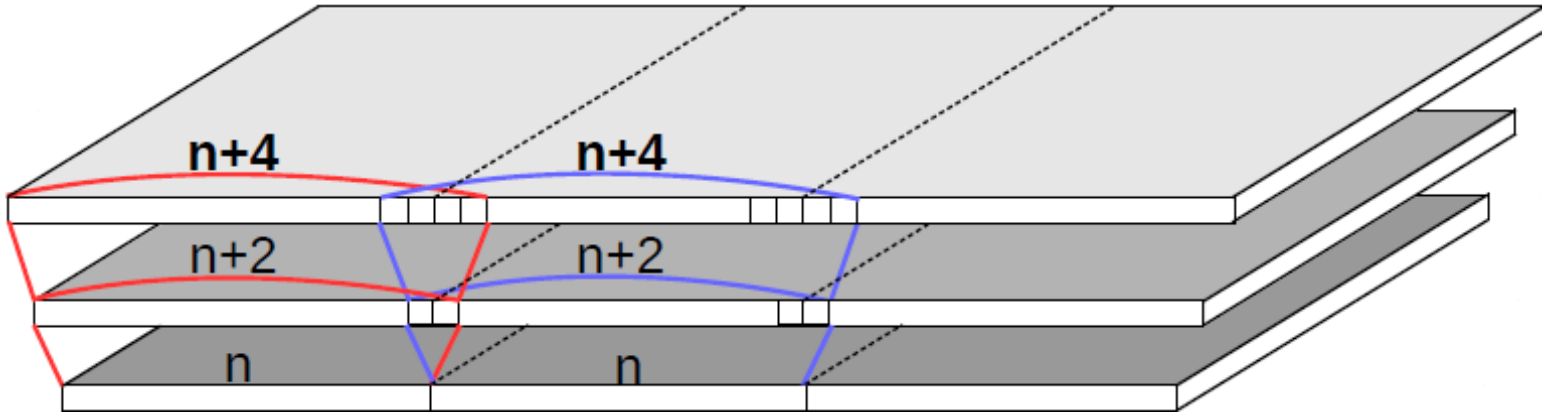

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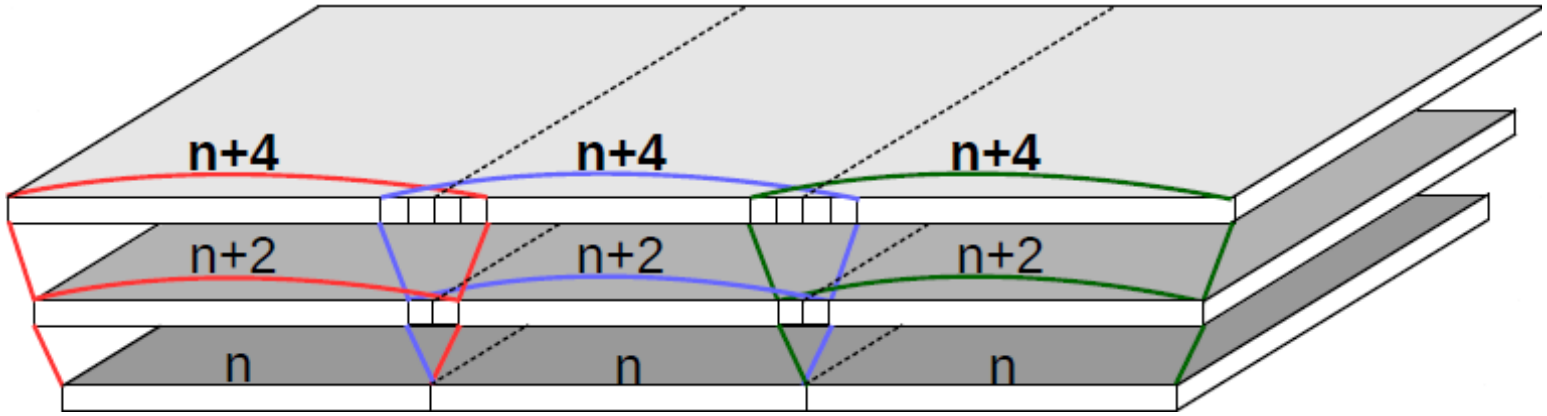

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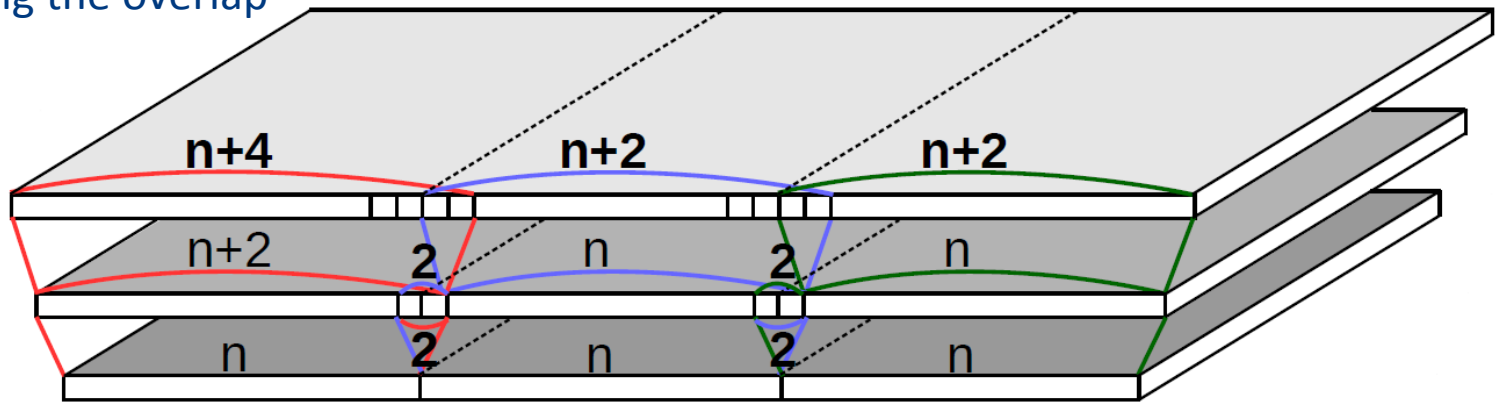

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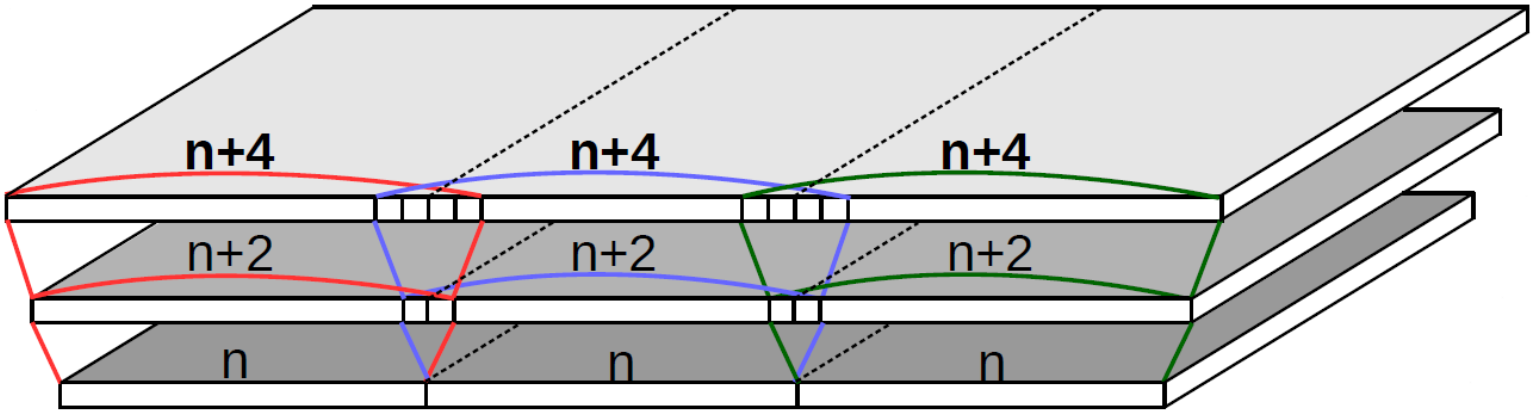

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Polyhedral Modeling

The Polyhedral Model and Recomputation

- Execution order is defined by the schedule

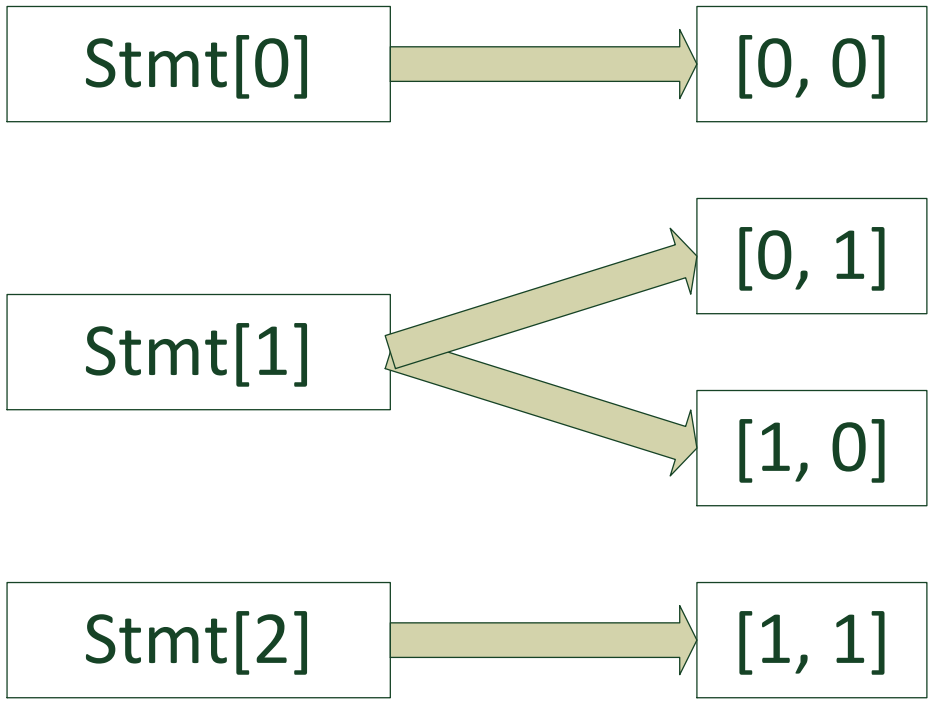
- Schedule is singular valued
  - One execution time per statement
  - One statement per execution time

- Recomputation:
  - Statements are executed multiple times
  - Non-singular valued schedules are required

Including Recomputation

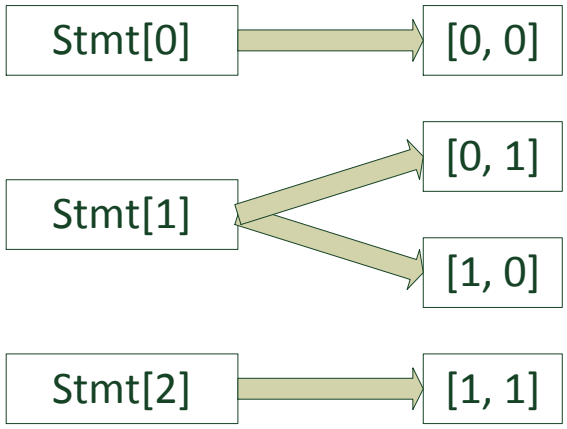
- Support for non-singular valued schedules
- Transforming non-singular valued schedules to singular valued schedules

Example



Example

Old Schedule



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Result: NewSchedule
set Lexmin to the lexographical minimum of OriginalSchedule;
if *OriginalSchedule is equal to Lexmin* **then**
    set newSchedule to OriginalSchedule;
else
    add a dimension to newSchedule;
    set i to 0;
    RestofSchedule = OriginalSchedule - Lexmin;
    while *RestofSchedule is not empty* **do**
        add Lexmin to newSchedule with the new dimension set to i;
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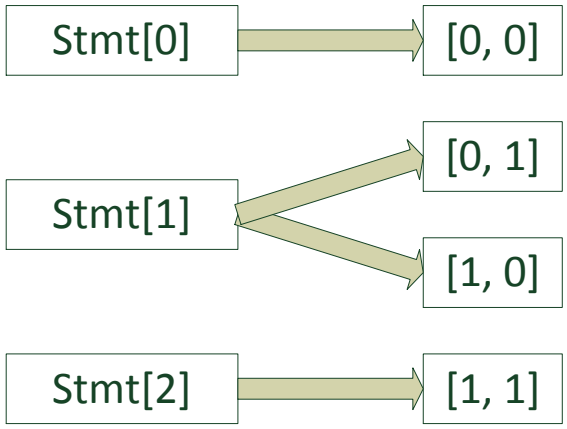

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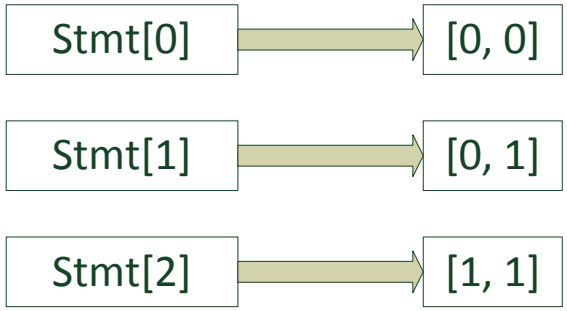

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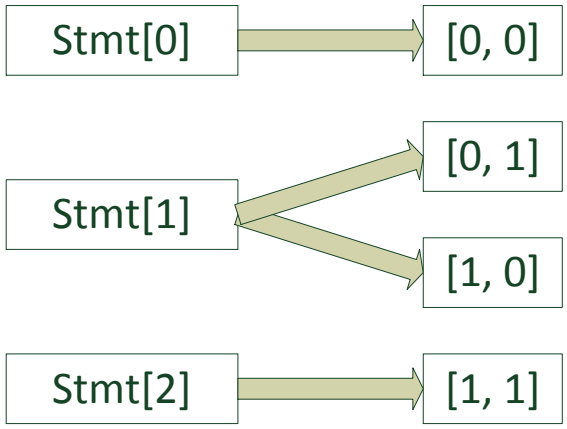

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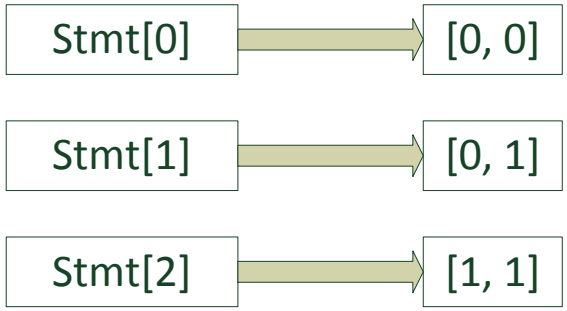


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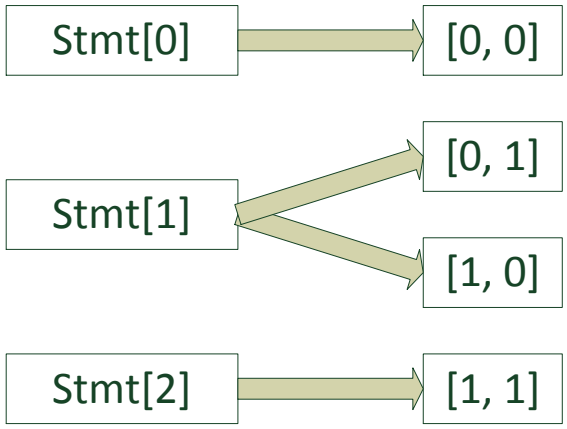

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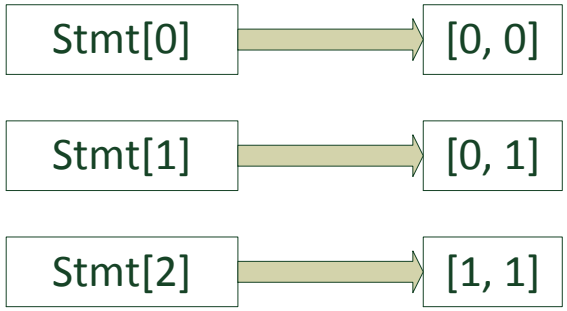

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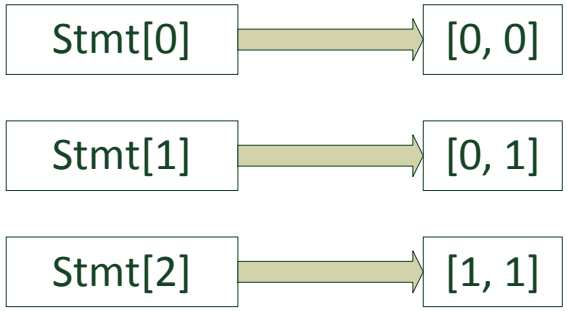
Example

Rest of Schedule

Lexicographical Minimum

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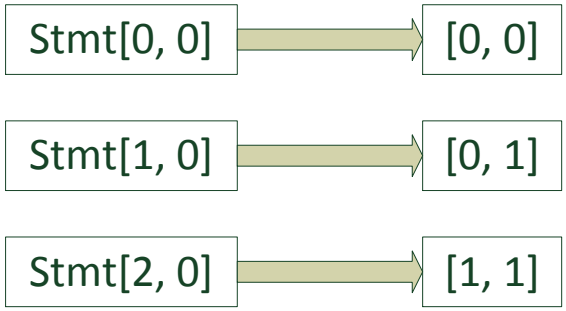
Example

Rest of Schedule

New Schedule

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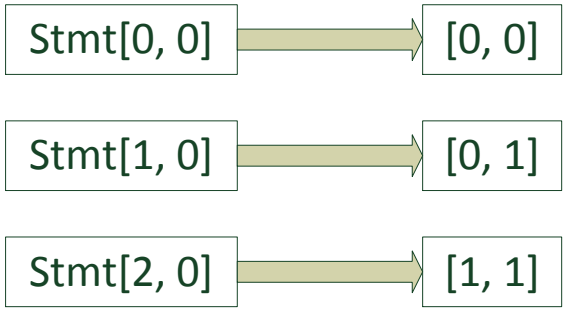


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Lexicographical Minimum

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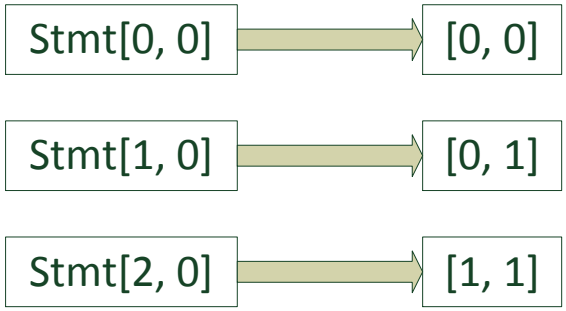


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Example

Lexicographical Minimum

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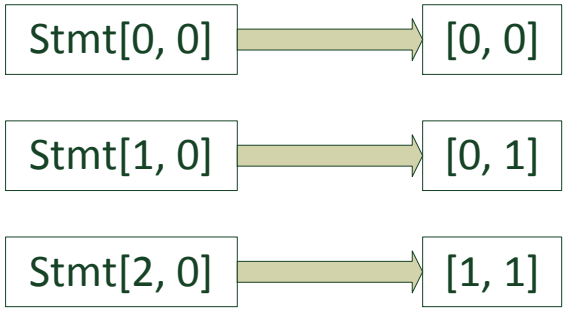


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Example

Lexicographical Minimum

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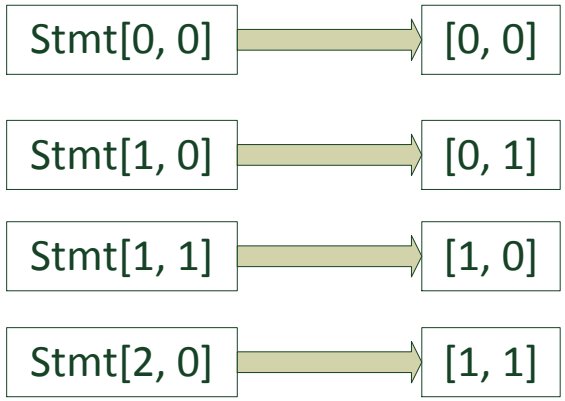


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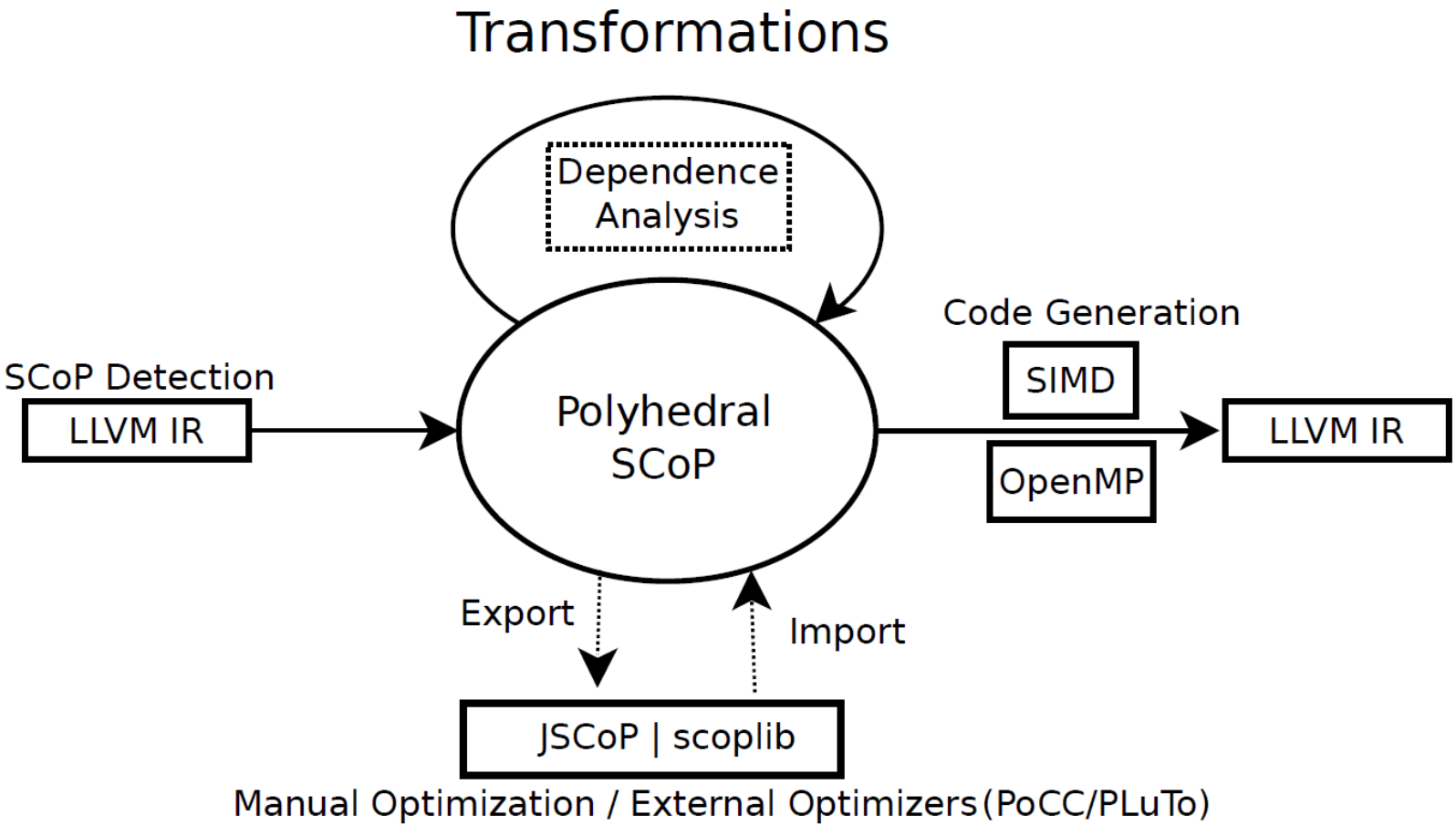
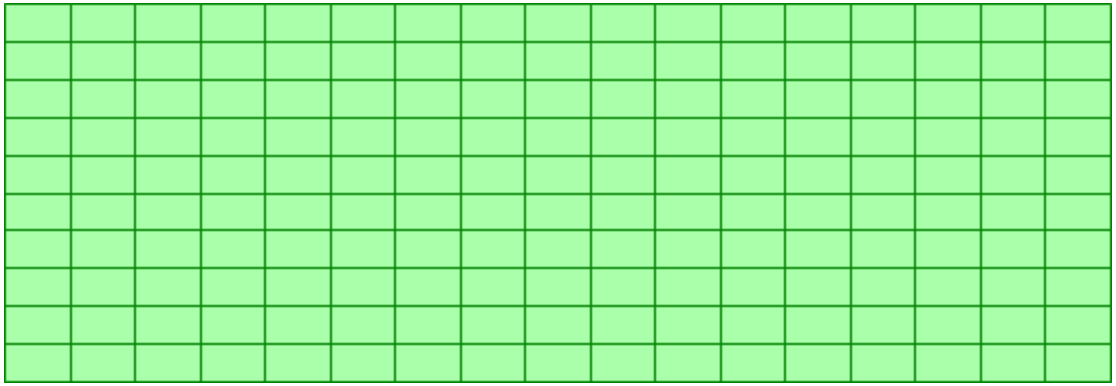
Including Recomputation: location

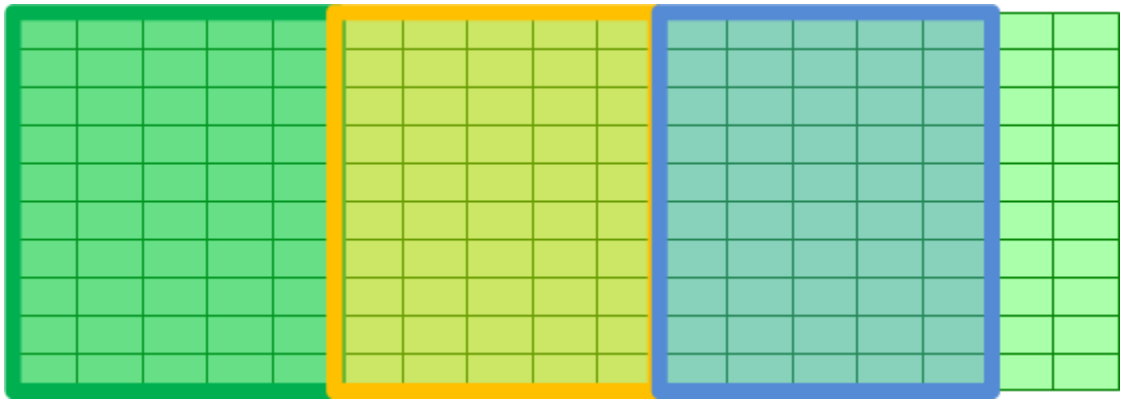


Jscop Implementation



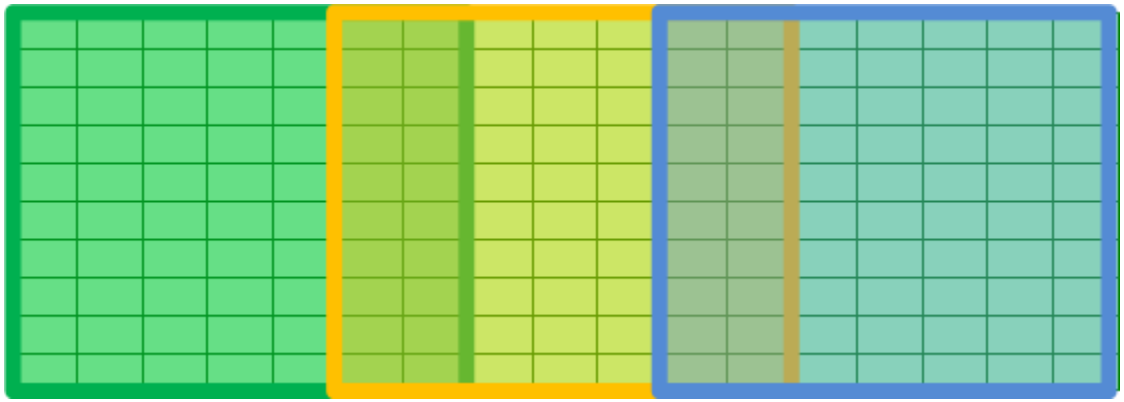
Conv[i0,i1,i2,i3] → [i0,i1,i2,i3]

Jscop Implementation



Conv[i0,i1,i2,i3] →[t0,i1,t1,i2,i3] :
0 <= t0 < no_tiles and
0 <= t1 < tilesize and
i0 = tilesize ∗ t0 + t1

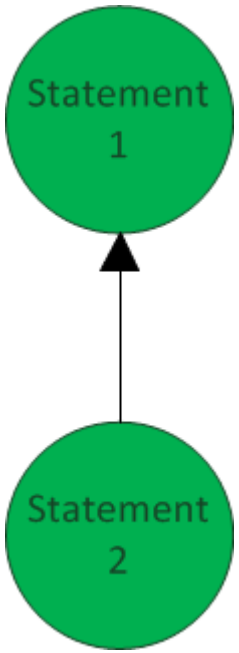
Jscop Implementation



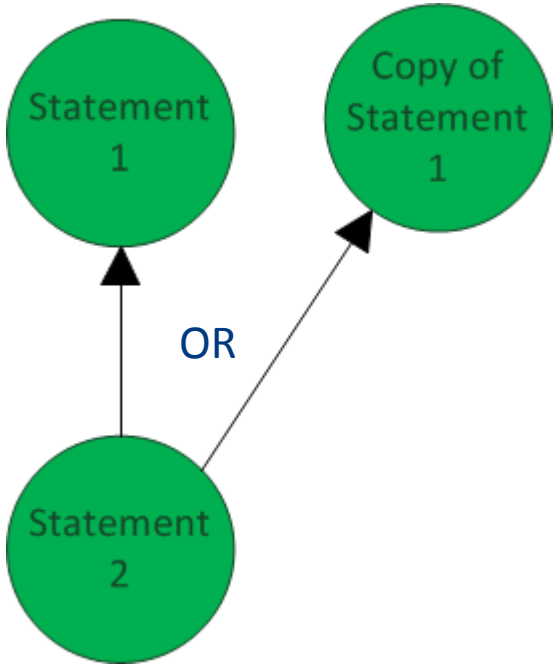
Conv[i0,i1,i2,i3] →[t0,i1,t1,i2,i3] :
0 <= t0 < no_tiles and
0 <= t1 < tilesize + overlap and
i0 = tilesize ∗ t0 + t1

Dependencies

Before



After



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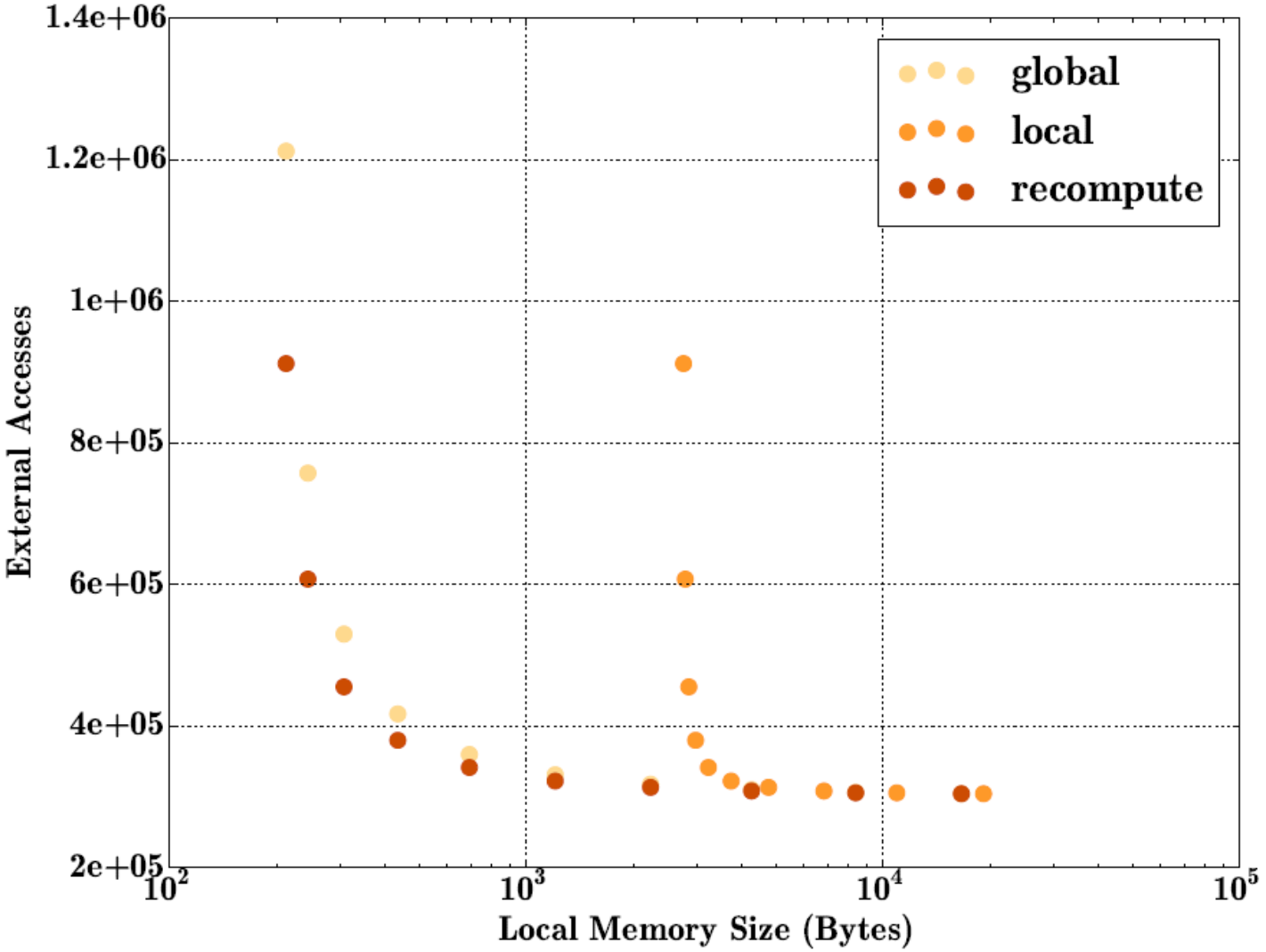
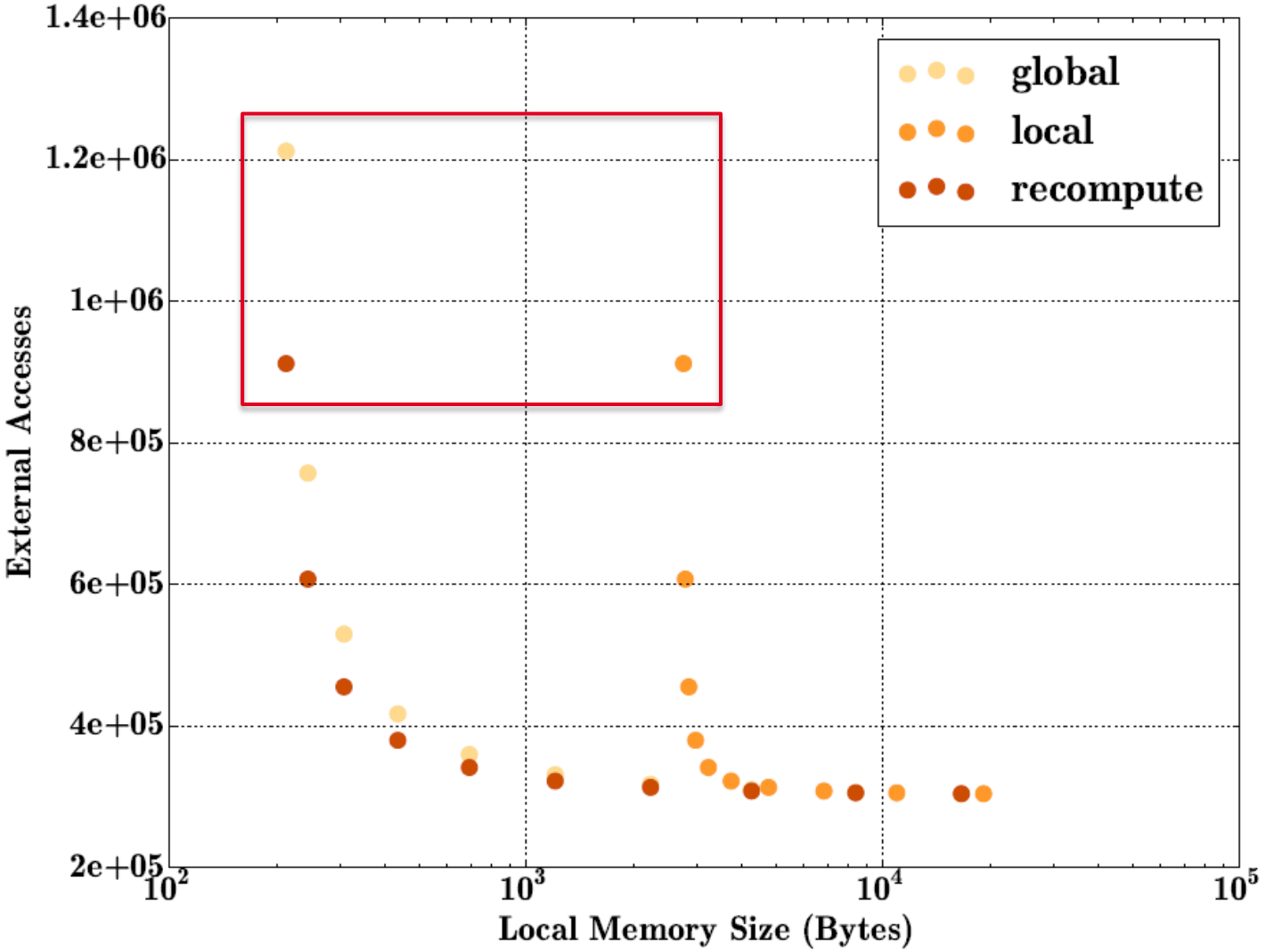
Experimental Results

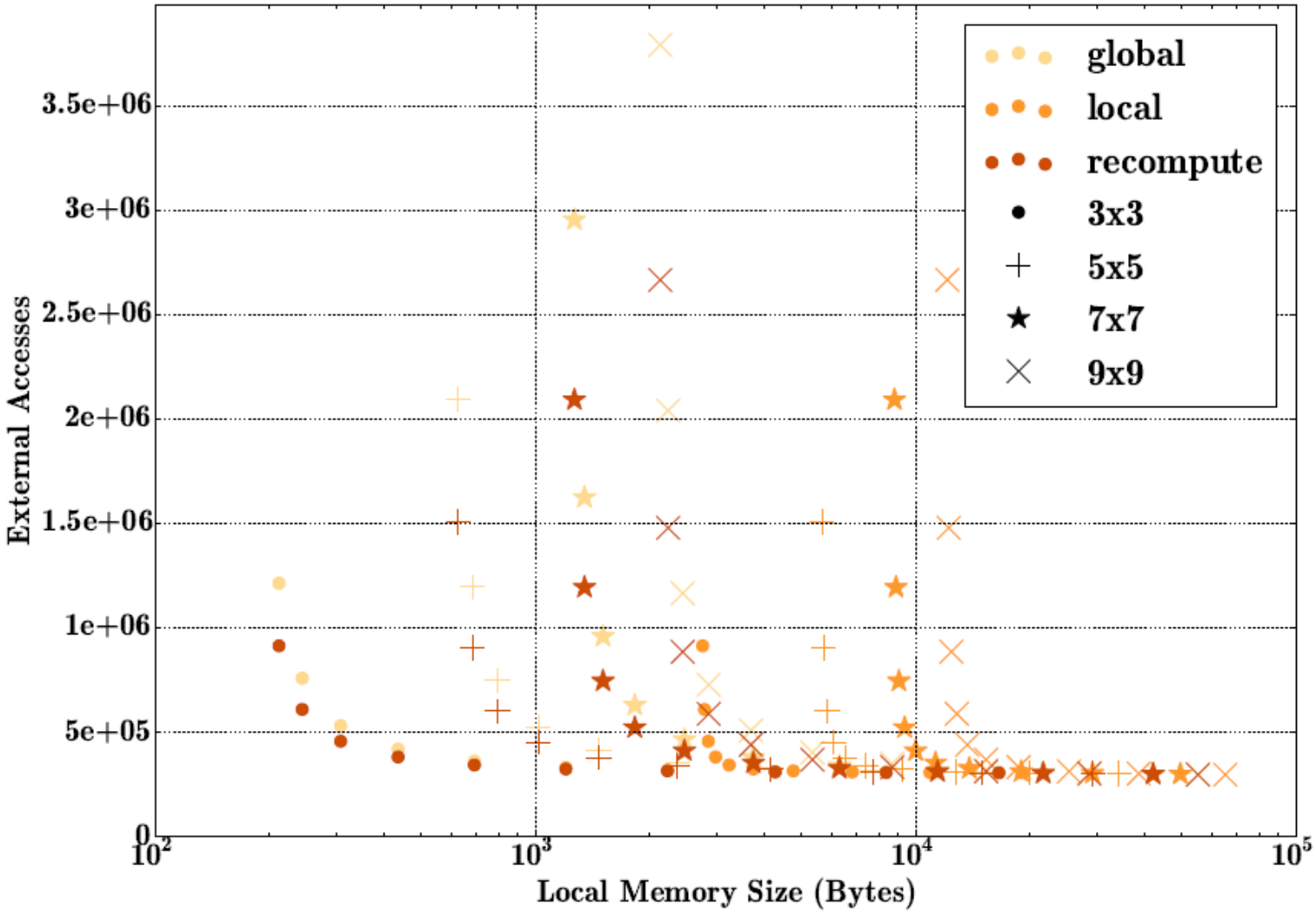
Results for different tile sizes



Results for different tile sizes



Results for different tile sizes and several kernel sizes



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Conclusion and Future Work

Conclusion

- An example CNN application which includes recompute
- Extension of Polly
- Demonstration of the effectiveness of recomputation

Future Work

- Legality Checks
- Model of the effects
- More applications

And Finally…

- Questions?
- Remarks?
- Suggestions?