Visualization of Data Movements and Accesses

Til Mohr

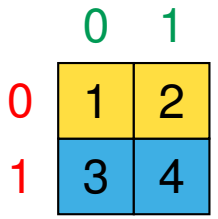
i12 High Performance Computing
RWTH AACHEN UNIVERSITY

Sum of Matrix Elements

Listing 1: Matrix Summation

```
1 let matrix = Matrix::random(2, 2);
2 let mut sum = 0;
3 for column in 0..2 {
4   for row in 0..2 {
5     sum += matrix.get(row, column);
6   }
7 }
8 sum
```

Matrix:



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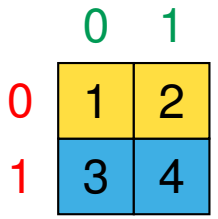

Matrix in Memory:

Sum of Matrix Elements

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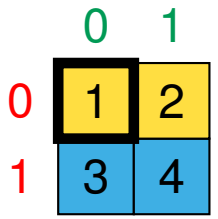
Matrix:



Matrix in Memory:

Current Item:

Cache:

Number of cache misses: **0**

Sum of Matrix Elements

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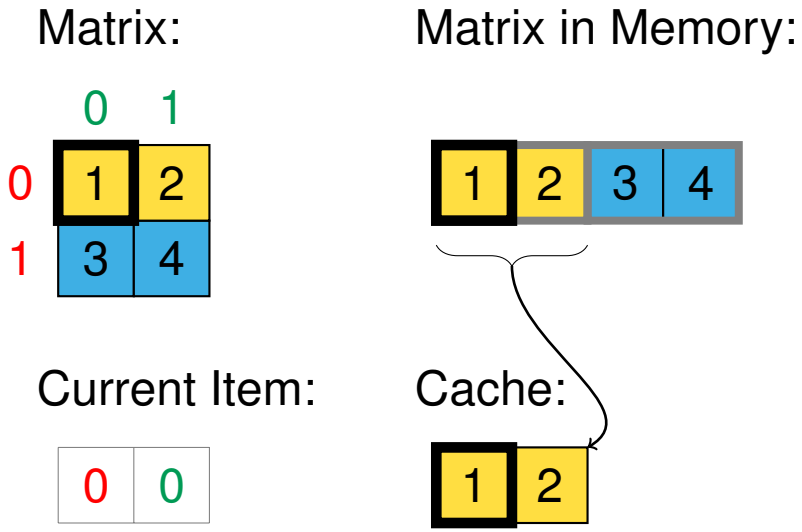

Number of cache misses: **1**

Sum of Matrix Elements

Listing 1: Matrix Summation

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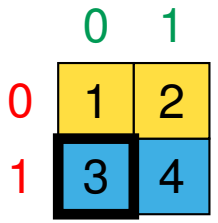
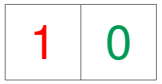
Matrix:

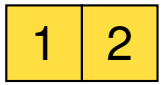


Matrix in Memory:

Current Item:



Cache:



Number of cache misses: **1**

Sum of Matrix Elements

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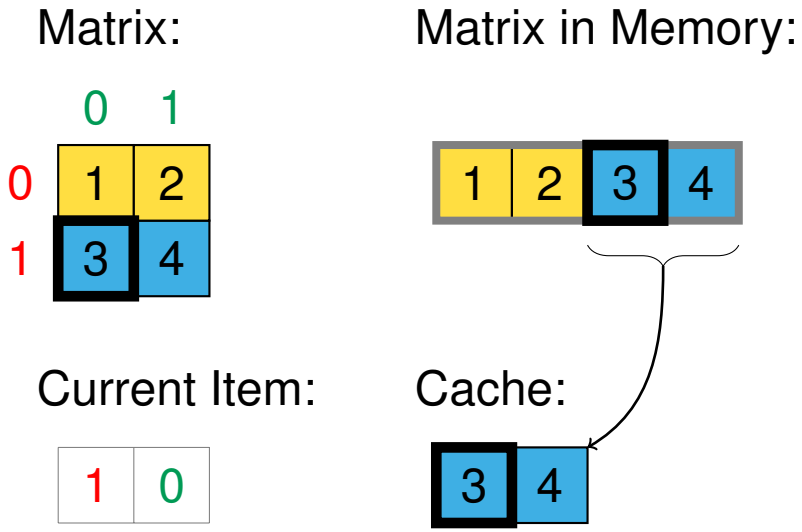

Number of cache misses: **2**

Sum of Matrix Elements

Listing 1: Matrix Summation

```
1 let matrix = Matrix::random(2, 2);
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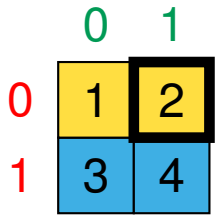
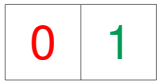
8 sum
```

Matrix:



Matrix in Memory:

Current Item:



Cache:

Number of cache misses: **2**

Sum of Matrix Elements

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1 let matrix = Matrix::random(2, 2);
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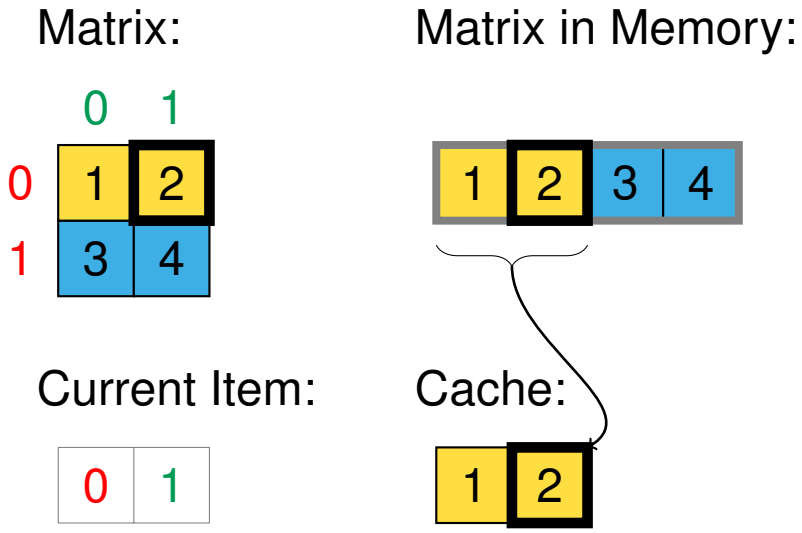

Number of cache misses: **3**

Sum of Matrix Elements

Listing 1: Matrix Summation

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1 let matrix = Matrix::random(2, 2);
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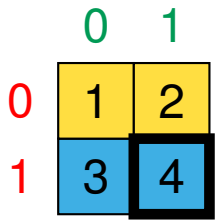
6   }
7 }
8 sum
```

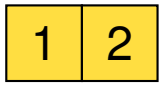
Matrix:



Matrix in Memory:

Current Item:

Cache:



Number of cache misses: **3**

Sum of Matrix Elements

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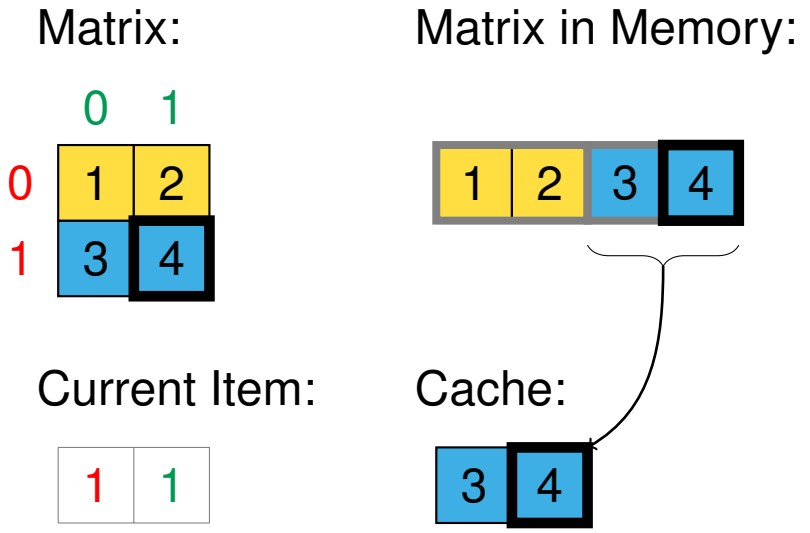

Number of cache misses: **4**

Sum of Matrix Elements - Reordered Loops

Listing 2: Matrix Summation

```
1 let matrix = Matrix::random(2, 2);
2 let mut sum = 0;
3 for row in 0..2 {
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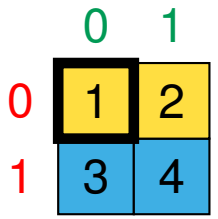
```

Matrix:



Matrix in Memory:

Current Item:

Cache:

Number of cache misses: **0**

Sum of Matrix Elements - Reordered Loops

Listing 2: Matrix Summation

```
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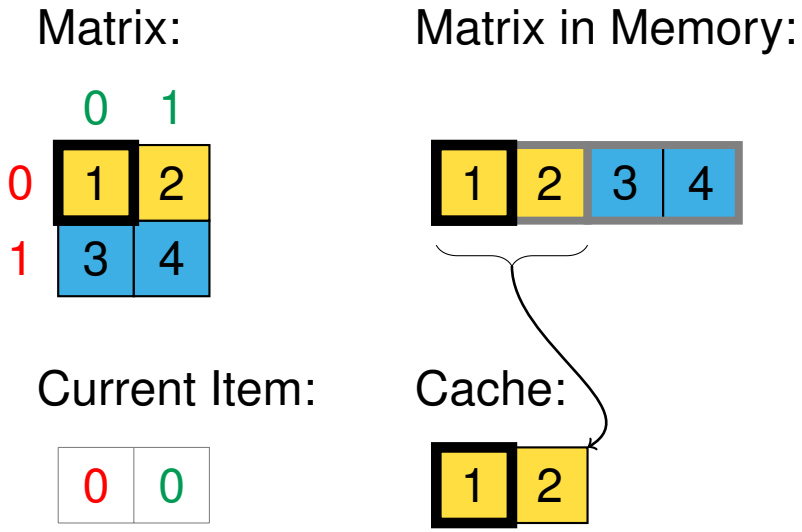

Number of cache misses: **1**

Sum of Matrix Elements - Reordered Loops

Listing 2: Matrix Summation

```
1 let matrix = Matrix::random(2, 2);
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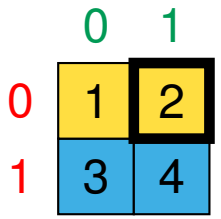
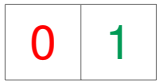
Matrix:

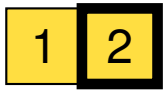


Matrix in Memory:

Current Item:



Cache:



Number of cache misses: **1**

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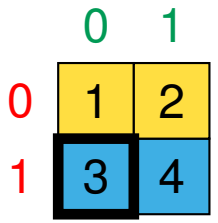

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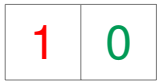

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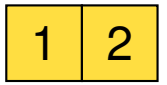

Number of cache misses: **1**

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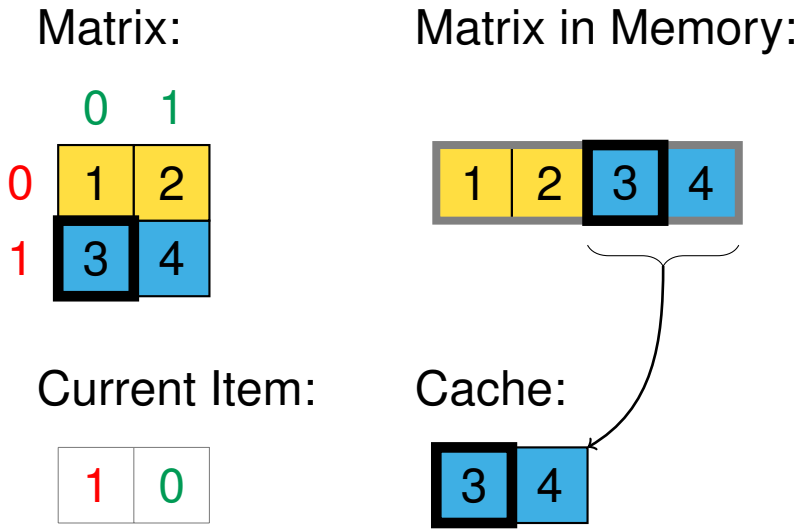

Number of cache misses: **2**

Sum of Matrix Elements - Reordered Loops

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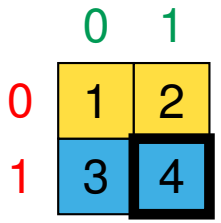


Matrix in Memory:

Current Item:

Cache:

Number of cache misses: **2**

Outline

- Memory-Related Performance Problems
  - Data Locality
  - Processor-Memory Performance Gap
- Overview of the Optimization Workflow

Memory-Related Performance Problems | Data Locality

$$t_{avg} = p \cdot t_c + (1 - p) \cdot t_m \tag{1}$$

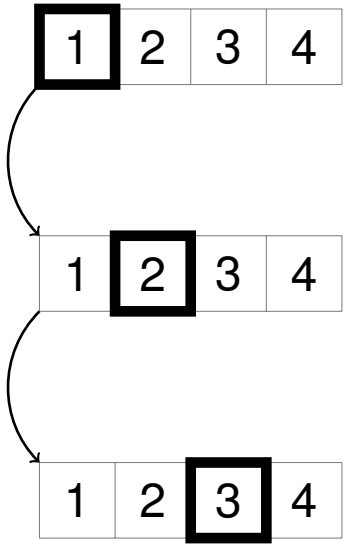
t_{avg} : average access time
p : cache hit percentage
t_c : cache access time
t_m : memory access time

$$t_c \ll t_m \tag{2}$$

Memory-Related Performance Problems | Data Locality

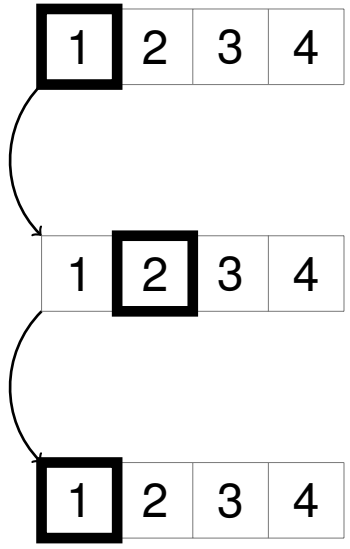
Spacial Locality

- Data that is referenced spatially close together is likely to be accessed in the near future

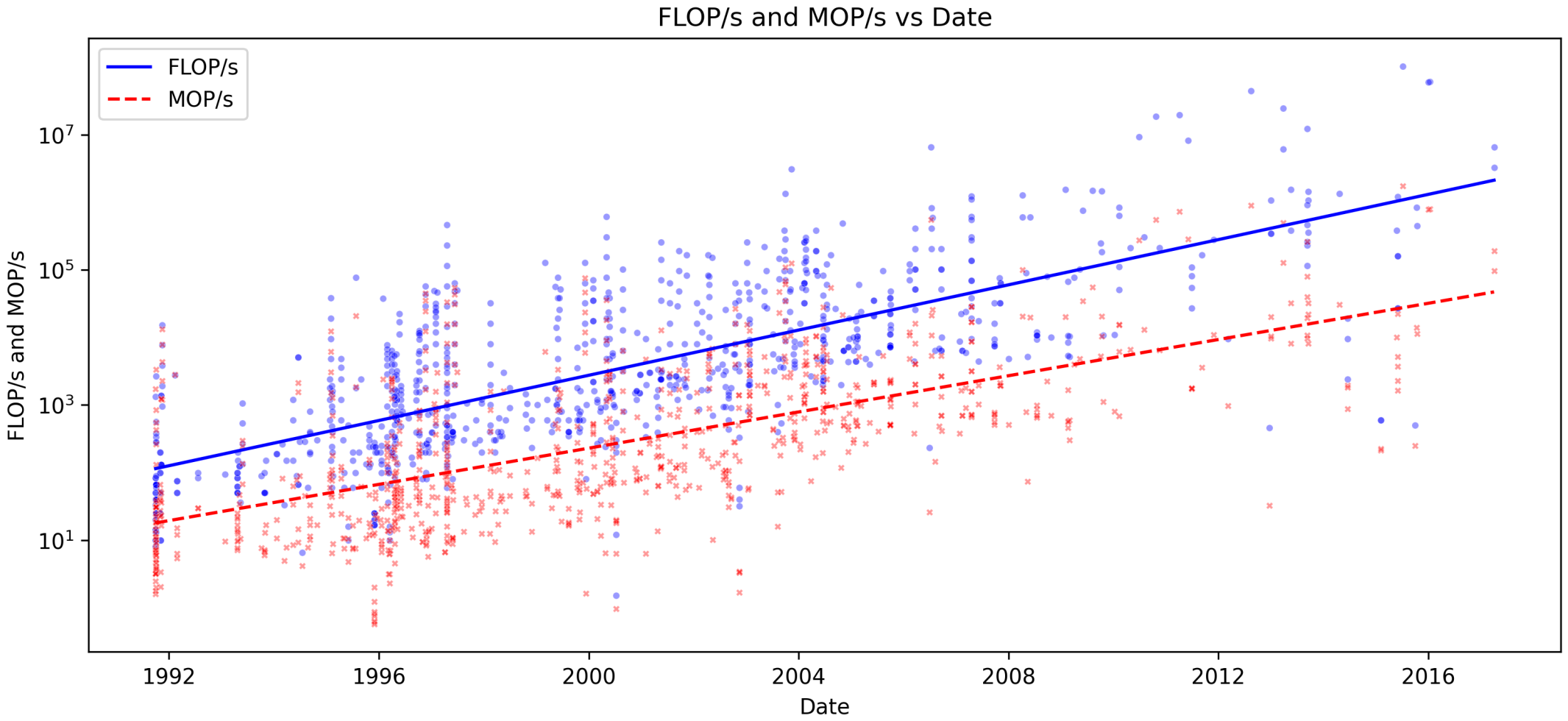


Temporal Locality

- Data that is referenced in the near past is likely to be accessed in the near future



Memory-Related Performance Problems | Processor-Memory Performance Gap



Overview of the Optimization Workflow

Visualization-Guided Optimization