CODE OPTIMISATION

ON INTEL XEON (CO)PROCESSORS

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Agenda

- The Case Study
- Identifying Inefficiencies
  - Common code pitfalls
  - Using compiler flags
- Vectorisation
- Shared Memory Parallelisation
- Intel Xeon Phi Coprocessor

The Case Study

```
void matMult (float **a, float **b, float **c, int size) {
    for (int i = 0; i < size; i++)
        for (int j = 0; j < size; j++) {
            c[i][j] = 0;
            for (int k = 0; k < size; k++)
                c[i][j] += a[i][k] * b[k][j];
        }
}
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Common Code Inefficiencies

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- Row/Column major - *work assignment…*

Avoidable Memory Accesses

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void matMult (float **a, float **b, float **c, int size) {
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		for (int j = 0; j < size; j++) {
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}
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- Solution:
  - Use a temporary variable to store intermediate results

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- Solution:
  - General C++ case prefer references over pointers!
  - Give hints to the compiler (pragmas or restrict)

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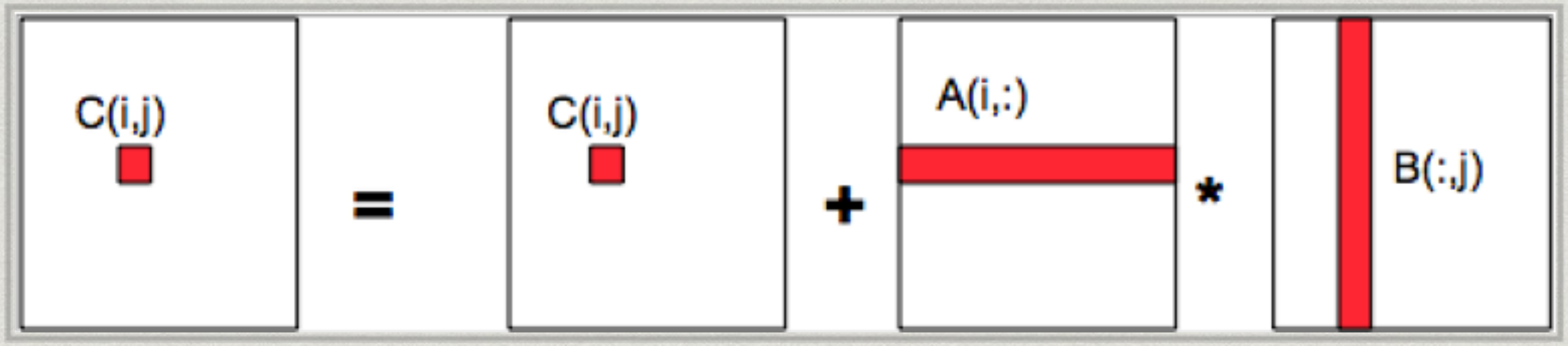
- Solution:
  - Guarantee the proper alignment of data structures manually

Blocking/Tiling



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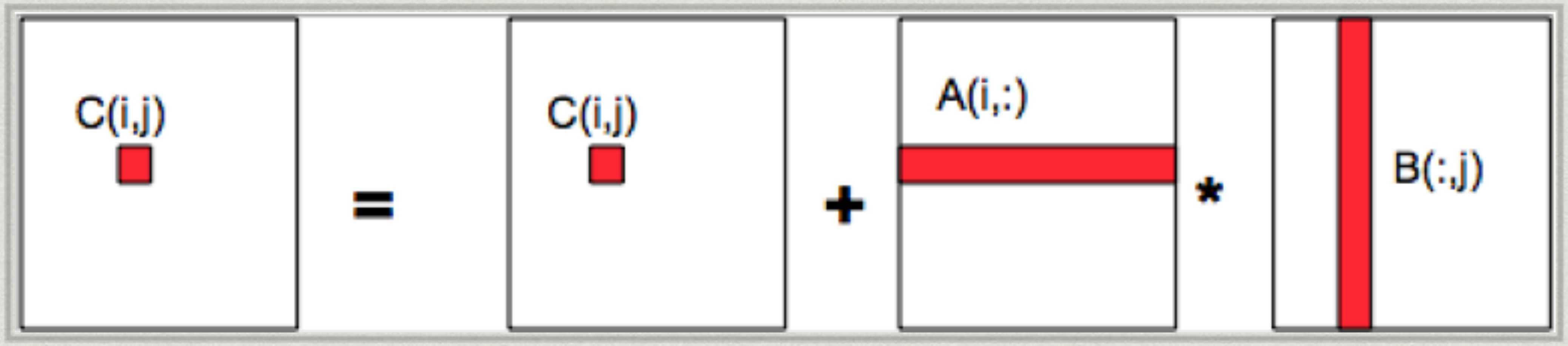
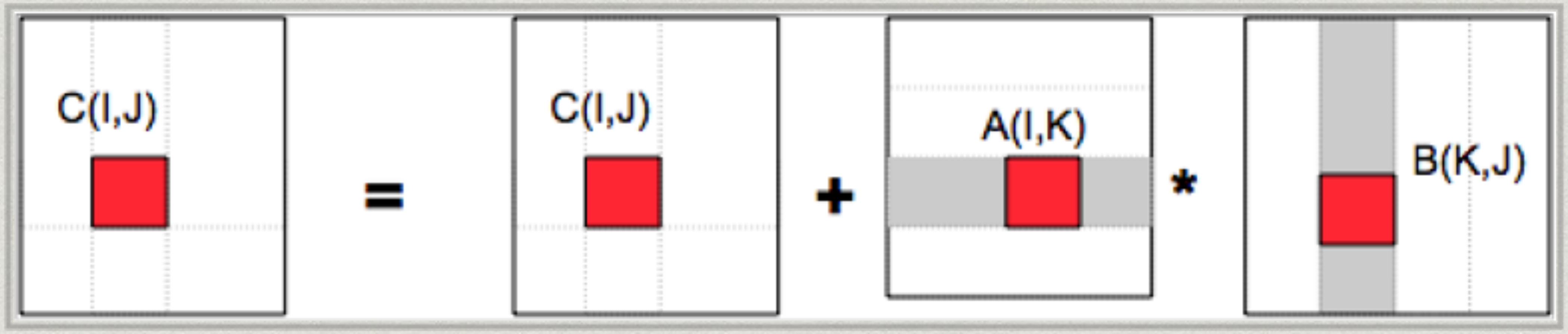
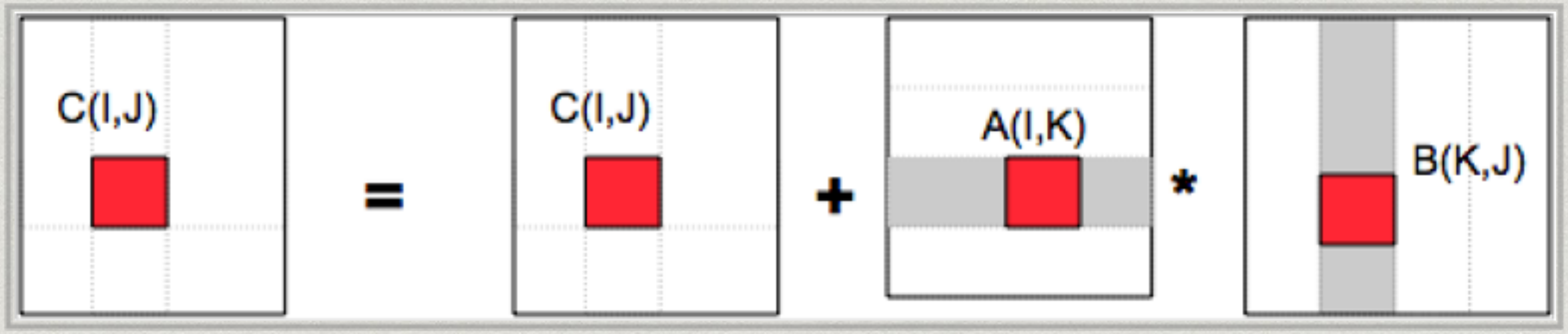




Blocking/Tiling

```
for I = 1 to N
    for J = 1 to N
     {read block C(I,J) into fast memory}
     for K = 1 to N
          {read block A(I,K) into fast memory}
          {read block B(K,J) into fast memory}
           do a matrix multiply on blocks to compute block C(I,J)
     {write block C(I,J) back to slow memory}
```



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- “Free lunch” speedups!

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  - Reduces both code size and execution time
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- -O2
  - Performs almost all supported optimisations
  - Generates faster code without compromising the space
- -O3
  - Almost all available optimisations without considering any trade-off

Vectorisation

- How is it achieved? By hand?

```
void matrixAdd (void) {
	__m256 ymm1, ymm2;

	for (unsigned i = 0; i < SIZE; ++i) {
		for (unsigned j = 0; j < VEC_SIZE; ++j) {
			ymm1 = _mm256_load_ps(&m1[i][j * 8]);
			ymm2 = _mm256_load_ps(&m2[i][j * 8]);

			ymm1 = _mm256_add_ps(ymm1, ymm2);
			_mm256_store_ps(&result[i][j * 8], ymm1);
		}
	}
}
```

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src/matrix.cpp(102): (col. 3) remark: PERMUTED LOOP WAS VECTORIZED.
src/matrix.cpp(102): (col. 3) remark: REMAINDER LOOP WAS VECTORIZED.
src/matrix.cpp(105): (col. 4) remark: loop was not vectorized: not inner loop.
src/matrix.cpp(101): (col. 2) remark: loop was not vectorized: not inner loop.
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```
src/matrix.cpp(244): (col. 2) remark: loop was not vectorized: existence of vector dependence.
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```
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                                    ) {
                         size; k++)
                    c[i][j] += a[i][k] * b[k][j];
          }
}
```

Vectorisation

- Vectorisation report ICC: -vec-reportX, where X
  - 1 - Loops successfully vectorised
  - 2 - Loops not vectorised (and the justification)
  - 3 - Adds dependency information
  - 4 - Non-vectorised loops report
  - 5 - Non-vectorised loops report with dependency information

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  - #pragma vector always
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- Avoid nested loops
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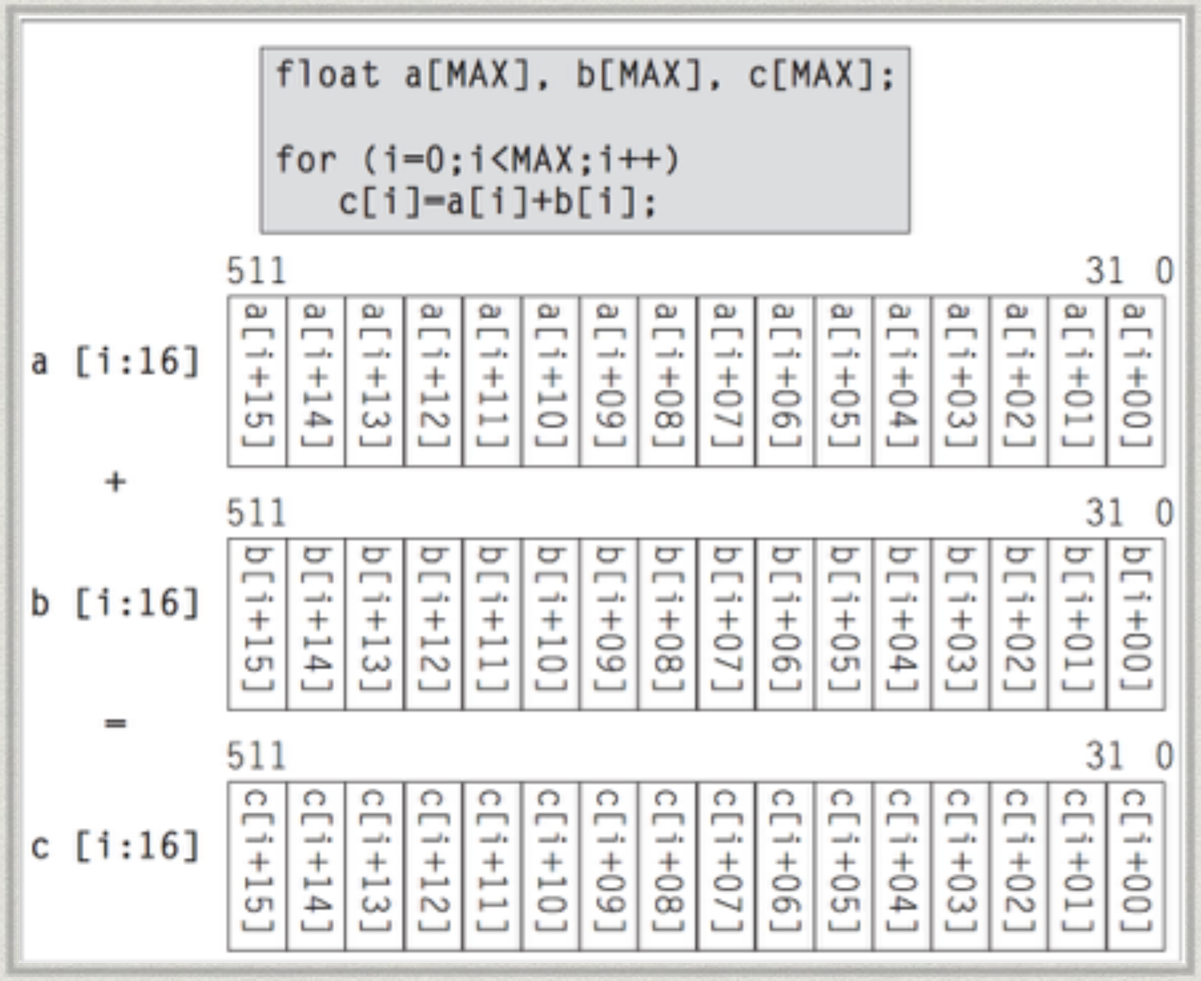
- Data alignment and layout

Data Layout

- Ensure that vector operations are applied to packed data; Ex. 512-bit Xeon Phi registers



Data Alignment

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* Ensure that the memory allocation of static data structures is properly aligned

Data Alignment

- Ensure that the memory allocation of static data structures is properly aligned
- Depends on the size of the vector registers
  - `__attribute__((align(DIM_SIMD))) float a [SIZE];`

EXERCISES - PART I

Exercise 1

- Perform basic code optimisations
- Parallelise code execution for shared memory systems
- https://bitbucket.org/ampereira/matrix-optimization/downloads

Shared Memory Parallelism

- Several libraries to produce parallel code for shared memory environments
  - **OpenMP**
  - TBB
  - CILK
  - …

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- Add the <omp.h> header to the code and use the pragmas

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- Options:
  - num_threads
  - schedule(X)
  - private(X)

Go In-depth

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* Definition of the task grain

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* Parallel tasks for irregular problems
* Nested parallelism

EXERCISES - PART II

Using Intel Composer on SeARCH

- Always have 2 terminal windows open
  - The computing node (interactive *qsub*)
  - The frontend, where the code is compiled
- Run *module load intel/2013.1.117* on both windows
  - In the computing node to set the dynamic library paths
  - In the frontend to use the compiler, headers, etc
- If you get "Catastrophic error: could not set locale "" to allow processing of multibyte characters" do *export LC_ALL=C*

References

- An Overview of Programming for Intel® Xeon® processors and Intel® Xeon Phi™ coprocessors, James Reinders, Intel
- Intel® Xeon Phi™ Coprocessor High Performance Programming, Jim Jeffers, James Reinders, Elsevier Waltham (Mass.), 2013
- Intel® 64 and IA-32 Architectures Software Developer's Manual