INTEL® MKL V.2019 - BLAS, JIT FEATURE

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CONFIGURATIONS INTEL® PARALLEL STUDIO XE

Composer Edition	Professional Edition	Cluster Edition
Intel® Fortran Compiler Intel® C++ Compiler **Intel® Math Kernel Library** Intel® Integrated Performance Primitives Intel® Data Analytics Acceleration Library Intel® Threading Building Blocks ® Cilk™ Plus & Intel® OpenMP*	Intel® Fortran Compiler Intel® C++ Compiler **Intel® Math Kernel Library** Intel® Integrated Performance Primitives Intel® Data Analytics Acceleration Library Intel® Threading Building Blocks Intel® Cilk™ Plus & Intel® OpenMP*	Intel® Fortran Compiler Intel® C++ Compiler **Intel® Math Kernel Library** Intel® Integrated Performance Primitives Intel® Data Analytics Acceleration Library Intel® Threading Building Blocks Intel® Cilk™ Plus & Intel® OpenMP*
	Intel® Advisor XE Intel® Inspector XE Intel® VTune™ Amplifier XE	Intel® Advisor XE Intel® Inspector XE Intel® VTune™ Amplifier XE Intel® MPI Library Intel® Trace Analyzer and Collector
Bundle or Add-on: Rogue Wave IMSL* Library	Add-on: Rogue Wave IMSL* Library	Add-on: Rogue Wave IMSL* Library

Additional configurations including, floating and academic, are available at: http://intel.ly/perf-tools

INTEL® MATH KERNEL LIBRARY (INTEL® MKL)

Linear Algebra

- BLAS
- LAPACK
- ScaLAPACK
- Sparse BLAS
- PARDISO* SMP & Cluster
- Iterative sparse solvers

Fast Fourier Transforms

- Multidimensional
- FFTW interfaces
- Cluster FFT

Vector Math

- Trigonometric
- Hyperbolic
- Exponential
- Log
- Power
- Root

Deep Neural Networks

- Convolution
- Pooling
- Normalization
- ReLU
- Inner Product

Summary Statistics

- Kurtosis
- Variation coefficient
- Order statistics
- Min/max
- Variance-covariance

And More

- Vector RNGs
- Splines
- Interpolation
- Trust Region
- Fast Poisson Solver

WHAT'S NEW IN INTEL® MKL V.2019 BETA

- **Introduced new functions to JIT (create) optimized S/DGEMM–like matrix multiply kernels for small matrix sizes (m,n,k <=16)**

- Introduced Extreme{EVD/SVD} functionality

- Introduce SparseQR functionality

- Introduced Multinominal Random Number Generators

- Improved performance of 1D/3D FFT

INTEL® MKL – BLAS JIT API

- Types

```
typedef enum {MKL_JIT_ERROR, MKL_JIT_SUCCESS, MKL_NO_JIT} mkl_jit_status_t;

typedef (*{s,d}gemm_jit_kernel_t)(void*, FP_TYPE*, FP_TYPE*, FP_TYPE*)
```

- **Functions:**

```
mkl_jit_status_t mkl_jit_create_{s,d}gemm(void** jitter, MKL_LAYOUT
layout, MKL_TRANSPOSE transa, MKL_TRANSPOSE transb, MKL_INT m, MKL_INT n, MKL_INT k,
FP_TYPE alpha, MKL_INT lda, MKL_INT ldb, FP_TYPE beta, MKL_INT ldc)

{s,d}gemm_jit_kernel_t mkl_jit_get_{s,d}gemm_ptr(void* jitter)

mkl_jit_status_t mkl_jit_destroy(void* jitter)
```

INTEL® MKL – BLAS JIT , DETAILS

- Language supported: C (CBLAS interface only) and Fortran (same function name as C API)

- All architectures supported, by default pointer to standard GEMM is returned

- JIT only for AVX2, AVX512 and M, N, K ≤ 16

- MKL_DIRECT_CALL_JIT

- Return status of mkl_jit_create_?gemm

  - Memory allocation fails: MKL_JIT_ERROR

  - JIT happened: MKL_JIT_SUCCESS

  - Standard GEMM is returned: MKL_NO_JIT

- Limitations: CNR features are not supported

INTEL® MKL – BLAS JIT , EXAMPLE

```c
int main() {
    MKL_INT m = 10, n = 5, k = 12, lda = 32, ldb = 32, ldc = 32;
    MKL_TRANSPOSE transa = MKL_NOTRANS, transb = MKL_TRANS;
    MKL_LAYOUT layout = MKL_COL_MAJOR;
    float alpha = 2.0, beta = 1.0;
    float *a, *b, *c;
    void* jitter_s_10_5_12;

    // allocate and initialize matrices
    mkl_jit_status_t status = mkl_jit_create_sgemm(&jitter_s_10_5_12, layout, transa, transb, m, n, k,
                                                   alpha, lda, ldb, beta, ldc);

    if (MKL_JIT_ERROR == status) {
        printf("Creation jitter failed\n");
        return 1;
    }
    sgemm_jit_kernel_t sgemm_10_5_12 = mkl_jit_get_sgemm_ptr(jitter_s_10_5_12);

    sgemm_10_5_12(jitter_s_10_5_12, a, b, c);          ⟸ perform C = alpha * A x B + beta*C

    mkl_jit_destroy(jitter_s_10_5_12);
    // free matrices
    return 0;
}
```

INTEL® MKL – BLAS JIT USAGE, ACTIVITY

- Open and review C examples:
  - small_gemm.c   jit_small_gemm.c   makefile
- Set compiler's environment:
  - sourse opt/intel/compilers_and_libraries_2018/linux/bin/**compilervars.sh intel64**
- Compiling and Linking :

    icc –mkl small_gemm.c

    icc -DMKL_DIRECT_CALL -std=c99 -I${MKL_INCL} -mkl   small_gemm.c

- Refer to MKL Linker Adviser : https://software.intel.com/en-us/articles/intel-mkl-link-line-advisor

INTEL® MKL - BLAS JIT USAGE, ACTIVITY

#Building:

make

#Run and record the Executions times:

./run.sh

Note: be aware that CPU supports AVX2 and or AVX-512 ISA:

cat /proc/cpuinfo | grep avx2 (avx512)

```
C:\AR\JIT_Demo\res.txt
[gfedorov@skl3 JIT_Demo]$ ./run.sh
[2 x 2], SGEMM Execution Time        == 1.769513e-07
[2 x 2], JIT_SGEMM Execution Time    == 4.656613e-08

[3 x 3], SGEMM Execution Time        == 1.750886e-07
[3 x 3], JIT_SGEMM Execution Time    == 4.656613e-08

[4 x 4], SGEMM Execution Time        == 1.806766e-07
[4 x 4], JIT_SGEMM Execution Time    == 4.097819e-08

[6 x 6], SGEMM Execution Time        == 1.825392e-07
[6 x 6], JIT_SGEMM Execution Time    == 5.029142e-08

[8 x 8], SGEMM Execution Time        == 1.918525e-07
[8 x 8], JIT_SGEMM Execution Time    == 4.656613e-08

[12 x 12], SGEMM Execution Time      == 2.142042e-07
[12 x 12], JIT_SGEMM Execution Time  == 7.078052e-08

[16 x 16], SGEMM Execution Time      == 2.272427e-07
[16 x 16], JIT_SGEMM Execution Time  == 8.195639e-08

[20 x 20], SGEMM Execution Time      == 3.259629e-07
Error: mkl_no_jit, exit
```

INTEL® MKL – BLAS JIT USAGE, ACTIVITY --DIRECT_CALL

MKL_DIRECT_CALL_JIT :

- make jitdirect

```
icc -DMKL_DIRECT_CALL_JIT -std=c99 -I${MKL_INCL} small_gemm.c -o jit_direct.out  -Wl,--
start-group   ${2019}/mkl/lib/intel64/libmkl_intel_lp64.a
${2019}/mkl/lib/intel64/libmkl_intel_thread.a ${2019}/mkl/lib/intel64/libmkl_core.a  -Wl,--
end-group -liomp5 -lpthread -lm -ldl
```
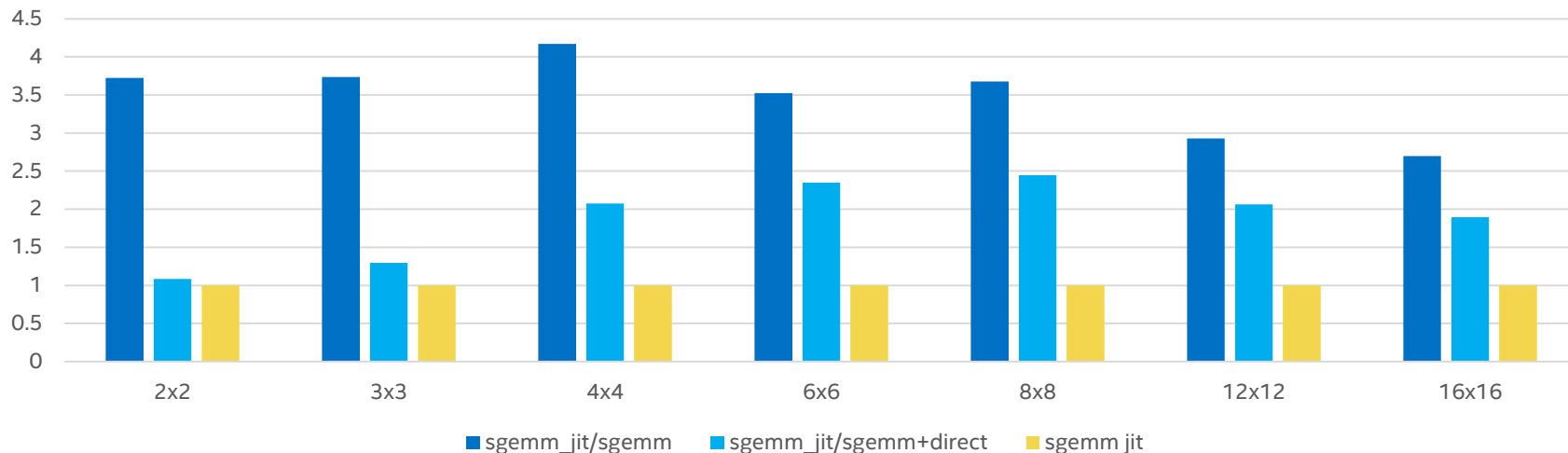
- run: ./jitdirect.out <size>,   size = {2, 3, 4, 6, 8, 12, 16, 20}

- Compare the performance results with previous calls

Conclusions? Do you see something like this?

```
[4 x 4], SGEMM        Execution Time  ==  17. 69513e-08
[4 x 4], SGEMM JIT  Execution Time  ==  7.078052e-08
[4 x 4], JIT_SGEMM Execution Time  ==  4.097819e-08
```

INTEL® MKL – BLAS, PERFORMANCE, SMALL SIZES

JIT SGEMM, Performance Ratio

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