INTEL® MATH KERNEL LIBRARY (INTEL® MKL) SMALL MATRIX MULTIPLICATION OPTIMIZATIONS USING JIT COMPILATION

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Outline

- Problem statement and solutions
- Simple example
- Performance comparison

Overheads for small sizes

- Low vectorization
- Low parallelization
- Non-local data access for large leading dimensions
- Error checking
- High function call overheads
  - Dispatching to ISA-specific codepath

Methods for improving performance for small sizes

- Specific kernels
- Compile-time optimizations
- Just-in-time (run-time) compilation
- Batching operations together
  - Modifying data layout

Direct call compilation flags for Intel MKL

Define the preprocessor macro `MKL_DIRECT_CALL` or `MKL_DIRECT_CALL_SEQ`

- Instead of calling a library function, a C implementation may be used
- Starting from Intel MKL 2018.1, compiler intrinsics may be used for some kernels

Starting from Intel MKL 2019 Beta: `MKL_DIRECT_CALL_JIT` or `MKL_DIRECT_CALL_SEQ_JIT`

- A JIT-ted kernel may be used

```
// compile with: icc -DMKL_DIRECT_CALL …
#include <mkl.h>
void main(void) {
    dgemm(…);
}
```

```
! compile with: ifort -DMKL_DIRECT_CALL -fpp …
#     include “mkl_direct_call.fi”
      program DGEMM_MAIN
      DGEMM(…)
```

Intel MKL JIT API

```
// Declare variables and initialize data (not shown)
void *jitter;
// Create jitter handle and generate GEMM kernel
mkl_jit_status_t status = mkl_jit_create_sgemm(&jitter, layout, transA,
         transB, m, n, k, alpha, lda, ldb, beta, ldc);
// Check that creation was successful
if (MKL_JIT_ERROR == status) {
    printf("Error: cannot create jitter\n");
    return 1;
}
// Get kernel associated with jitter handle
sgemm_jit_kernel_t kernel = mkl_jit_get_sgemm_ptr(jitter);
for (i = 0; i < nb; i++) {
    …
    kernel(jitter, a[i], b[i], c[i]); // Repeatedly execute the GEMM kernel
    …
}
mkl_jit_destroy(jitter); // Destroy the created jitter/GEMM kernel
```

Intel MKL JIT API

- Creates a handle on a jitter for sgemm

```
mkl_jit_status_t mkl_jit_create_sgemm(void **jitter, <sgemm paramters>)
```

- MKL_JIT_SUCCESS: indicates that a sgemm kernel has been generated;
  MKL_NO_JIT   : indicates standard sgemm function will be used;
  MKL_JIT_ERROR   : indicates an error happened due to lack of memory.

- Returns a function pointer to generated sgemm kernel

```
sgemm_jit_kernel_t mkl_jit_get_sgemm_ptr(const void *jitter)
```

- `typedef void (*sgemm_jit_kernel_t)(void *, float *, float *, float *)`

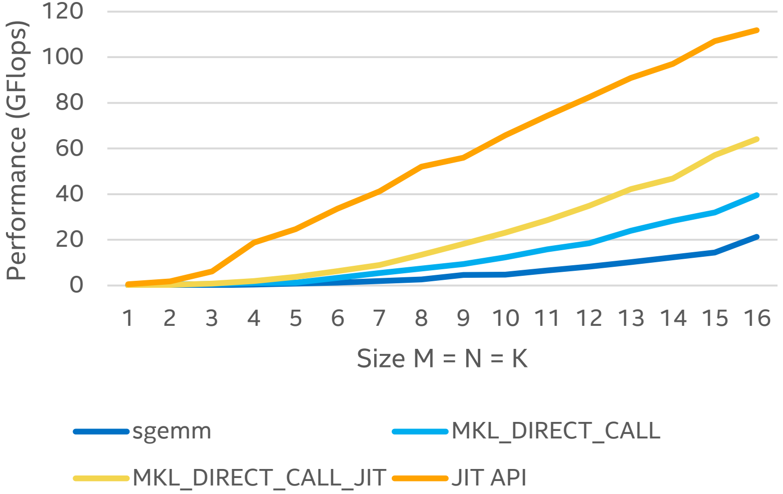
- Free the memory associated with code generator and sgemm kernel

```
mkl_jit_status_t mkl_jit_destroy(void *jitter)
```

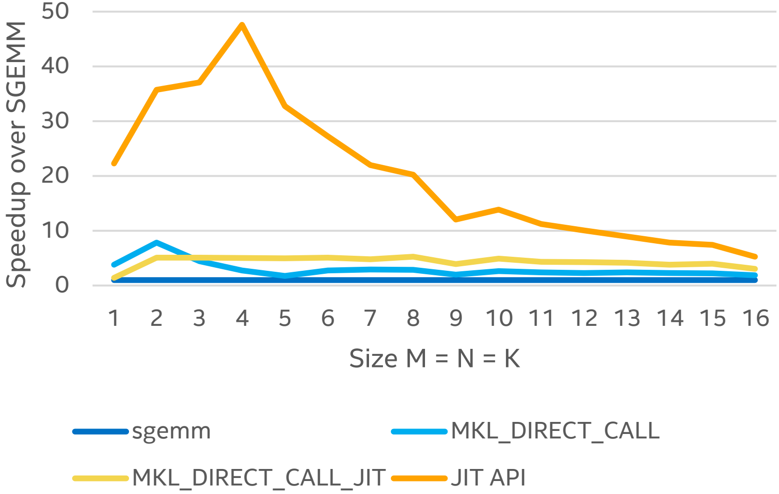
Optimization Notice

Performance of SGEMM on Intel® Xeon® Platinum

Intel® MKL 2019 Gold Performance of SGEMM and Variants



Intel® MKL 2019 Gold Speedup over SGEMM



Configuration: Intel® Xeon® Platinum 8180, 2x28 cores, 2.5 GHz, 376 GB RAM, OS Ubuntu, 16.04 LTS; Intel® MKL 2018.
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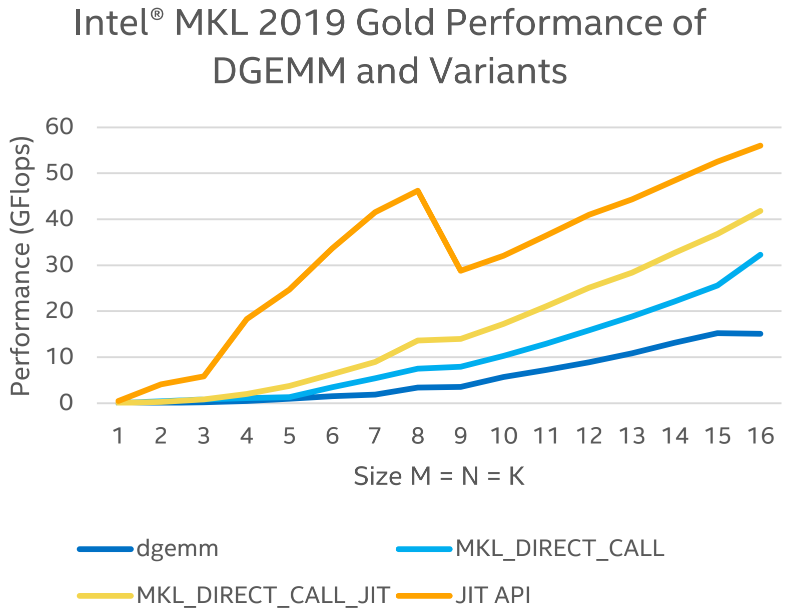
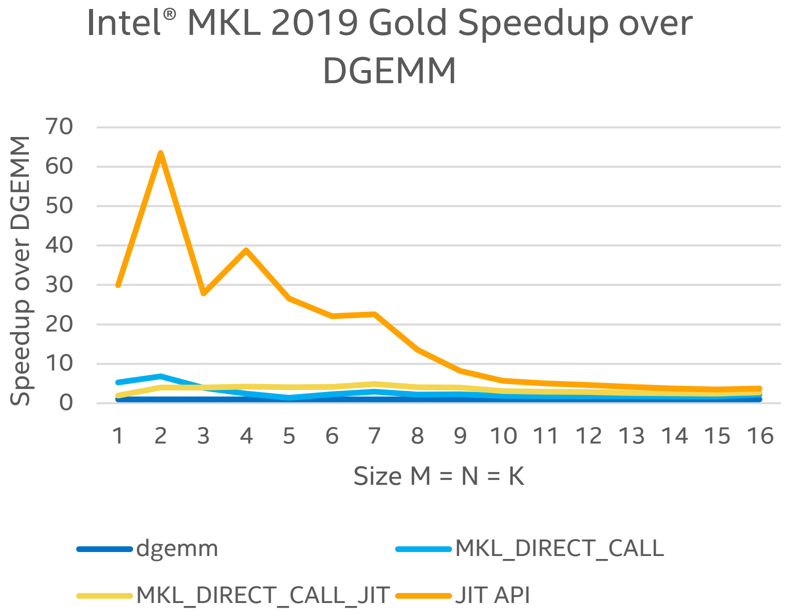
Performance of DGEMM on Intel® Xeon® Platinum





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Summary

- Small linear algebra problems:
  - Are ubiquitous
  - Suffer performance overheads
- Just-in-time compilation can help:
  - Generator can create customized kernels for any parameters
- Performance gains can be significant

Resources

- Intel MKL Developer Reference: https://software.intel.com/en-us/articles/mkl-reference-manual
- Intel MKL Forum: https://software.intel.com/en-us/forums/intel-math-kernel-library
- No cost option for Intel MKL: https://software.intel.com/en-us/articles/free-mkl
- Intel MKL-DNN: https://github.com/01org/mkl-dnn
- Xbyak: https://github.com/herumi/xbyak
- libxsmm: https://github.com/hfp/libxsmm

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