INTEL® MATH KERNEL LIBRARY, BLAS USAGE

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What's Inside Intel® MKL

Accelerate HPC, Enterprise, IoT & Cloud Applications

Linear Algebra
- **BLAS**
- LAPACK
- ScaLAPACK
- Sparse BLAS
- Iterative sparse solvers
- PARDISO*
- Cluster Sparse Solver

FFTs
- Multidimensional
- FFTW interfaces
- Cluster FFT

Neural Networks
- Convolution
- Pooling
- Normalization
- ReLU
- Inner Product

Vector RNGs
- Congruential
- Wichmann-Hill
- Mersenne Twister
- Sobol
- Neiderreiter
- Non-deterministic

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

Vector Math
- Trigonometric
- Hyperbolic
- Exponential
- Log
- Power
- Root

And More
- Splines
- Interpolation
- Trust Region
- Fast Poisson Solver

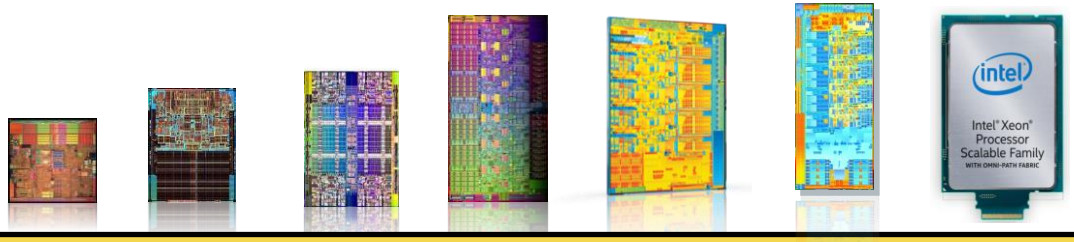
Intel® Architecture Platforms

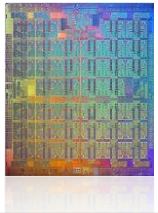
Operating System: Windows*, Linux*, MacOS[1]*

[1] Available only in Intel® Parallel Studio Composer Edition.

Automatic Dispatching to Tuned ISA-specific Code Paths

More cores → More Threads → Wider vectors





	Intel® Xeon® Processor 64-bit	Intel® Xeon® Processor 5100 series	Intel® Xeon® Processor 5500 series	Intel® Xeon® Processor 5600 series	Intel® Xeon® Processor E5-2600 v2 series	Intel® Xeon® Processor E5-2600 v3 series v4 series	Intel® Xeon® Scalable Processor[1]	Intel® Xeon Phi™ x200 Processor (KNL)
Up to Core(s)	1	2	4	6	12	18-22	28	72
Up to Threads	2	2	8	12	24	36-44	56	288
SIMD Width	128	128	128	128	256	256	512	512
Vector ISA	Intel® SSE3	Intel® SSE3	Intel® SSE4- 4.1	Intel® SSE 4.2	Intel® AVX	Intel® AVX2	Intel® AVX-512	Intel® AVX-512

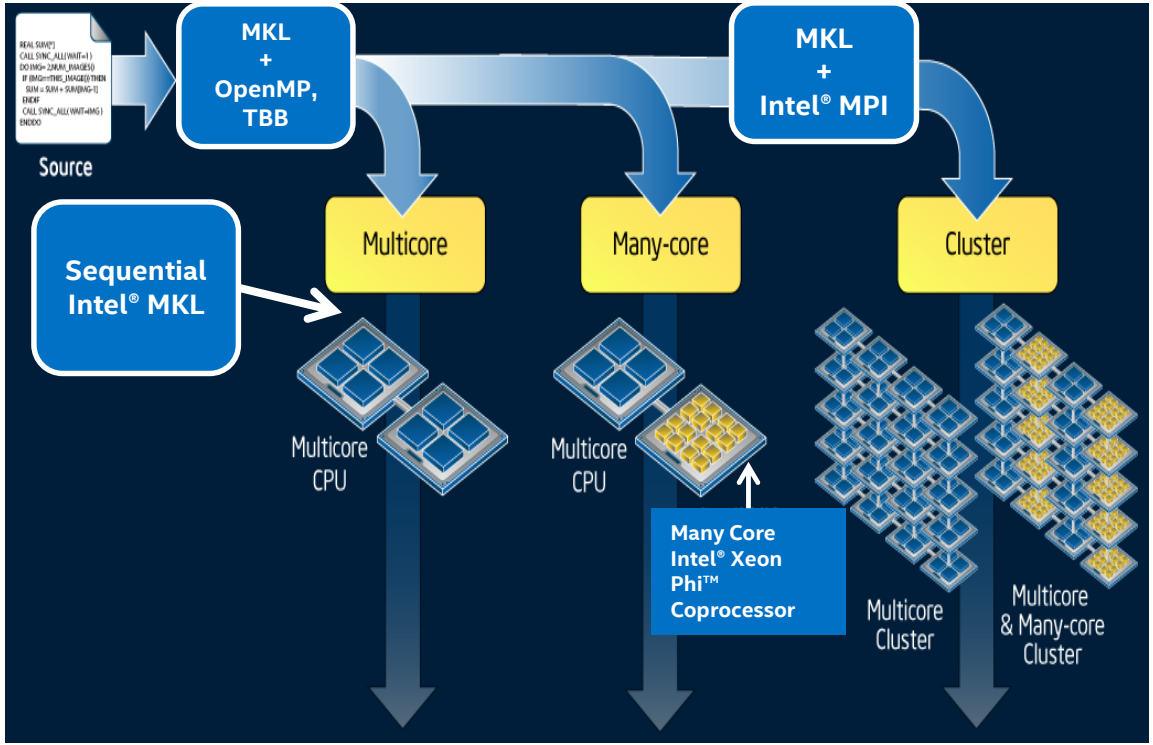
1. Product specification for launched and shipped products available on ark.intel.com.

Automatic Performance Scaling from the Core, to Multicore, to Many Core and Beyond

Intel® MKL

Extracting performance from the computing resources

- Core: **vectorization**, prefetching, cache utilization
- Multi-Many core (processor/socket) level **parallelization**
- Multi-socket (node) level **parallelization**
- Clusters **scaling**



Intel® MKL 2018 New Features and Optimizations

Intel® Xeon Phi™ Knights Mill Optimizations	DNN Convolution and Inner Product functions Single Precision Level 3 BLAS, including SGEMM New INT8 and INT16 GEMM functions
BLAS and LAPACK	Compact BLAS and LAPACK functions Direct Call LAPACK Cholesky and QR factorizations LU factorization and Inverse without pivoting Aasen-based factorization and solve functions Bounded Bunch-Kaufman (Rook) pivoting factorizations
FFTs	Verbose Mode Support
Vector Math - 24 New Functions	v?Fmod, v?Remainder v?Powr, v?Exp2, v?Exp10 v?Cospi, v?Sinpi, v?Tanpi, and more

Introduction

- Objective:
  - In these activities, you will run Intel® MKL DGEMM based code
  - Learn how to manage the output and performance
- Requirements:
  - Intel® Parallel Studio XE 2018 Composer Edition with Intel® C++ Compiler
  - **Linux*** OS supported by Intel® C++ Compiler
  - Recommended to have at least 3nd **generation Intel® Core™ processor** (with Intel® AVX2)
- **Time : 25 min**

Intel® MKL Lab – BLAS Usage **Activity #1**

Folder **day1/lab2 :**

mkl_test_v1.c, mkl_test_v2.c, mkl_test_v3.c

- review test: cat/less **mkl_test_v1.c.**
  - mkl_malloc, mkl_free, dsecnd,
  - roll_your_own_multiply,
  - Ddot_Multiply,
  - Dgemv_multiply,
  - Dgemm_multiply

Note – “https://software.intel.com/en-us/articles/a-simple-example-to-measure-the-performance-of-an-intel-mkl-function”

Intel® MKL Lab – BLAS Usage **Activity #1**

GEMM API: **C = alpha*op(A)*op(B) + beta*C**

$C_{m,n} = A_{m.k} * B_{k,n}$

```
void cblas_dgemm (
const CBLAS_LAYOUT Layout, const CBLAS_TRANSPOSE transa, const CBLAS_TRANSPOSE transb,
const MKL_INT m, const MKL_INT n, const MKL_INT k,
const double alpha, const double *a,
const MKL_INT lda, const double *b, const MKL_INT ldb,
const double beta, double *c, const MKL_INT ldc );
```

Intel® MKL Lab – BLAS Usage **Activity #1**

#Compiling and Linking:

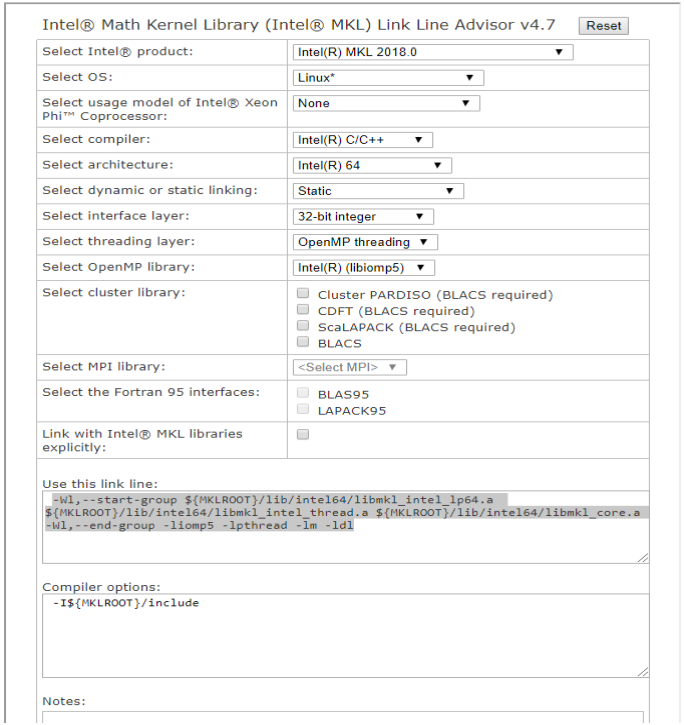
- Set compiler's environment:

source opt/intel/compilers_and_libraries_2018/linux/bin/**compilervars.sh intel64**

- **icc -mkl mkl_test_v1.c -o 1.out**

#MKL Linker Adviser :

https://software.intel.com/en-us/articles/intel-mkl-link-line-advisor



Intel® MKL Lab – BLAS Usage **Activity #1**

#Run and record execution times:

- ./1.out 1000
- ./1.out 2000
- ~~./1.out 4000~~

./1.out 1000

roll_your_own_multiply(). Elapsed time = ..., sec

Ddot_Multiply(). Elapsed time = ..., sec

Dgemv_multiply(). Elapsed time = ..., sec

Dgemm_multiply(). Elapsed time = ...,sec

Conclusion?

Intel® MKL Lab – BLAS Usage **Activity #2**

#review test: cat/less **mkl_test_v2.c**

- icc -mkl mkl_test_v2.c -o 2.out

#SCALABLITY: Run and record execution times

- export MKL_NUM_THREADS=1
  - ./2.out 8000 … Elapsed time = ….., sec
- export MKL_NUM_THREADS=2
  - ./2.out 8000 …. Elapsed time = ….., sec
- export MKL_NUM_THREADS=4
  - ./2.out 8000 …..Elapsed time = ….., sec

Conclusion?

Intel® MKL Lab – BLAS Usage **Activity #2**

mkl_test_v2.c : cblas_dgemm(….);

#Verbose Mode:

- export MKL_VERBOSE=1 // 0 by default

int mkl_verbose (true/false); // false by default

- **./2.out 8000**

MKL_VERBOSE Intel(R) MKL 2018.0 Update 2 Product build 20180127 for Intel(R) 64 architecture Intel(R) Advanced Vector Extensions 512 (Intel(R) AVX-512) enabled processors, Lnx 2.30GHz lp64 intel_thread

MKL_VERBOSE
DGEMM(N,N,8000,8000,8000,0x7fffbd682890,0x7f6d8a634080,8000,0x7f6d6bdeb080,8000,0x7fffbd682898,0x7f6d4d5a2080,8000) 4.65s CNR:OFF Dyn:1 FastMM:1 TID:0 NThr:4

Intel® MKL Lab – BLAS Usage **Activity #3**

#IA Dispatching

review test: cat/less **mkl_test_v3.c** : cblas_dgemm(….);

#Environment Variable:

MKL_ENABLE_INSTRUCTIONS == AVX512 | AVX2 | AVX | SSE4_2

#Runtime function:

int mkl_enable_instructions (int isa);

isa == MKL_ENABLE_AVX512 | MKL_ENABLE_AVX2 | MKL_ENABLE_AVX | MKL_ENABLE_SSE4_2

Intel® MKL Lab – BLAS Usage **Activity #3**

#IA Dispatching

mkl_test_v3.c : cblas_dgemm(….);

- icc -mkl mkl_test_v3.c -o 3.out
- export MKL_VERBOSE=1

#and run and record execution times:

- **./3.out 8000**
  - export MKL_ENABLE_INSTRUCTIONS=AVX2 … Elapsed time = ……, sec
  - export MKL_ENABLE_INSTRUCTIONS=AVX … Elapsed time = ……, sec
  - export MKL_ENABLE_INSTRUCTIONS=SSE4_2 …. Elapsed time = ……, sec
  - export MKL_ENABLE_INSTRUCTIONS=AVX512 … Elapsed time = ……., sec

Intel® MKL Lab – BLAS Usage **Activity #4**

#Conditional Numerical Reproducibility - CNR

mkl_test_v3.c

export MKL_ENABLE_INSTRUCTIONS=

export MKL_CBWR=**VALUE**

Value	Description
COMPATIBLE	Intel® Strea Intel® Streaming SIMD Extensions 2 (Intel® SSE2) without rcp
SSE2	Intel SSE2
SSE3	DEPRECATED. Intel® Streaming SIMD Extensions 3 (Intel® SSE3).
SSSE3	Supplemental Streaming SIMD Extensions 3 (SSSE3)
SSE4_1	Intel® Streaming SIMD Extensions 4-1 (Intel® SSE4-1)
SSE4_2	Intel® Streaming SIMD Extensions 4-2 (Intel® SSE4-2)
AVX	Intel® Advanced Vector Extensions (Intel® AVX)
AVX2	Intel® Advanced Vector Extensions 2 (Intel® AVX2)

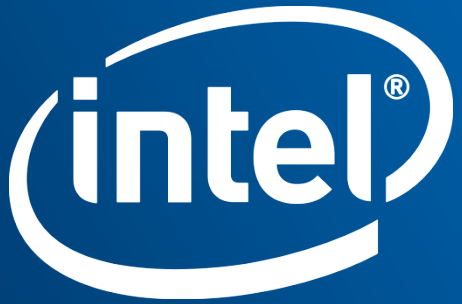
Intel® MKL Lab – BLAS Usage **Activity #4**

#Conditional Numerical Reproducibility - CNR

Run and record execution times

./3.out 8000

- export MKL_CBWR=AVX512 … Elapsed time = ….., sec
- export MKL_CBWR=AVX … Elapsed time = ……, sec
- export MKL_CBWR=SSE2 … Elapsed time = ……., sec
- export MKL_CBWR=COMPATIBLE …. Elapsed time = ……., sec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