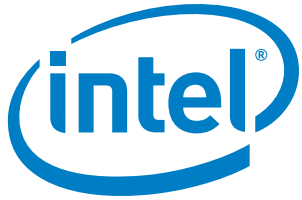

Intel® Math Kernel Library (Intel® MKL) 10.2

In-Depth

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Intel® Math Kernel Library (Intel® MKL) 10.2

Intel® Math Kernel Library (Intel® MKL) offers highly optimized, extensively threaded math routines for scientific, engineering, and financial applications that require maximum performance.

Intel MKL is available with the Intel® C++ and Fortran Compilers Professional Editions and Intel® Cluster Toolkit, as well as a standalone product.

Intel MKL provides high-performance, future proofing for applications and productivity for developers. Intel MKL is extremely optimized for current multicore x86 platforms and will continue to be optimized for future platforms to ensure applications benefit seamlessly from the latest architecture enhancements.

Microsoft Visual Studio* developers: Build robust technical applications more efficiently using the premier library of high-speed implementations of BLAS, LAPACK, FFTs, and Statistics functions from within Microsoft Visual Studio 2003*, 2005*, and 2008*.

Highlights

- Version 10.2 is now available. See below for a list of the new features and performance improvements.
- Intel MKL 10.2 is now optimized for Intel® Xeon® 5500 and Intel® Core™ i7 processors (previously codenamed Nehalem).
- See the system requirements for a full list of supported operating systems, compilers, and processors.
- Check out WhatIf.intel.com for interesting new technologies related to Intel MKL.

Features

Outstanding Performance on Intel® processors

Achieve leadership performance from the math library that is highly optimized for, Intel® Xeon®, Intel® Core™, Intel® Itanium®, and Intel® Pentium® 4 processor-based systems. Special attention has been paid to optimizing multithreaded performance for the Intel® Xeon® Quad-core processors and the new Intel® Core™ i7 Quad-Core processors. Intel MKL strives for performance, competitive with that of other math software packages on nonIntel® processors.

Multicore ready

- **Excellent scaling on multicore and multiprocessor systems**: Use the built-in parallelism of Intel MKL to automatically obtain excellent scaling on multicore and multiprocessors including Intel Xeon 5500 and the latest dual and quad-core systems. Intel MKL BLAS, Fast Fourier transforms, and Vector Math, among many other routines are threaded using OpenMP*.
- **Thread-Safety**: All Intel MKL functions are thread-safe. A nonthreaded sequential version of Intel MKL is also provided.

Automatic runtime processor detection

A runtime check is performed so that processor-specific optimized code is executed, ensuring that your application achieves optimal performance on whatever system it is executing on.

Support for C and Fortran interfaces

Intel MKL includes both C and Fortran interfaces, unlike some alternative math libraries that require you to purchase multiple products.

Support for all Intel® processors in one package

Intel MKL includes support for Intel® Xeon®, Intel® Core™, Intel® Pentium 4, Intel Itanium architectures in a single package. Alternative math libraries require you to purchase multiple products for all supported processors.

Royalty-free distribution rights

Redistribute unlimited copies of the Intel MKL runtime libraries with your software.

New in Intel MKL 10.2

This release of Intel Math Kernel Library (Intel MKL 10.2) provides optimized multithreaded performance for the newest Intel® processors, especially the Intel® Xeon® 5500 processor.

Performance Improvements

Performance improvements cover several key math routines including LINPACK, Out-of-core PARDISO, BLAS, and FFT. In addition, Intel AVX (Advanced Vector Extensions) support is included for advanced vectorization being introduced in upcoming Intel® architecture processors. This provides support for 256-bit vector operations, in many cases doubling performance. These are provided earlier to test and develop forward scaling in your applications.

C#/.Net support

Intel MKL 10.2 introduces C#/.Net support examples for calling Intel MKL functions.

BLAS

Introduce better coverage of threading in level 1 BLAS routines, in addition to the threading for level 2 and level 3 BLAS routines.

LAPACK

Intel MKL 10.2 includes complete support for LAPACK 3.2.

FFT

Intel MKL 10.2 introduces these key new additions to FFT:

- Scaling for scaling factors 1/N, 1/sqrt(N)

- Implement DFTI_FORWARD_SIGN

- Implement Radices mix of 7, 11, and 13

- Optimize real data transforms in Cluster FFT

Additionally, FFTW interfaces are included that support standardization for FFTs.

PARDISO

Intel MKL 10.2 introduces single precision support in PARDISO (Parallel Direct and Iterative Solvers) and several performance enhancements.

New in Intel® MKL 10.1

This release of Intel Math Kernel Library (Intel MKL 10.1) provides optimized multithreaded performance for the newest Intel® processors (Intel® Xeon® 7400 series, Intel® Core™). Intel® MKL 10.0 introduced a new "layered" architecture to better support the varied usage models of our users as well as merged the standard and cluster editions so there is a single comprehensive package.

Optimizations for the New Intel Xeon and Intel Core Processors.

For more information see section "Performance Improvements" in 10.1 on page 7.

"Layered" Architecture Introduced in Intel MKL 10.0

Intel MKL 10.0 introduced a rearchitected product to provide multiple layers so that the base Intel MKL package supports numerous configurations of interfaces, compilers, and processors in a single package. Many other library vendors have specific versions that must be first found, downloaded, installed, and tested depending on the particular configuration of your development environment. This new Intel MKL architecture is intended to provide maximum support for our varied customers' needs, while minimizing the effort it takes to obtain and utilize the great performance of Intel MKL. For more information, please refer to the "Using Intel MKL Parallelism" section of the Intel MKL User's Guide.

Computational Layer

This layer forms the heart of Intel MKL. A runtime check is performed so that processor-specific optimized code is executed. Users can build custom shared objects to include only the specific code needed and thus reduce the size of this layer if size is an issue.

PARDISO Direct Sparse Solver

- Out-of-core memory implementation for solving larger problems on SMP systems
- Support of separate backward/forward substitution for DSS/PARDISO
- A new parameter for turning off iterative refinement for DSS interface
- A new parameter for checking sparse matrix structure for PARDISO interface
- Sparse solver functionality now integrated into the core math library, and it is no longer necessary to link a separate solver library
- Sparse solver functionality that can now be linked dynamically

Sparse BLAS

- Added routines for computing the sum and product of two sparse matrices stored in compressed sparse row format
- Adder routines for converting between different sparse matrix formats
- Added support for all data types (single precision, complex and double complex)
- Added sparse 0-based indexing
- Added single precision support added
- Threaded Level-3 Sparse BLAS triangular solvers

LAPACK

- The capability to track and/or interrupt the progress of lengthy LAPACK computations has been added via a callback function mechanism. A function called mkl_progress can be defined in a user application, which will be called regularly from a subset of the MKL LAPACK routines. Refer to the specific function descriptions to see which LAPACK functions support the feature.

Discrete Fourier Transform Interface (DFTI)

- Added the DftiCopyDescriptor function for convenience when using the FFTs
- The size of statically linked executables calling DFTI has been reduced significantly.
- Complex storage now available for real-to-real transforms

Iterative Solver Preconditioner

- ILUT accelerator/preconditioner for the Intel MKL RCI iterative solvers

Vector Math Functions

- New Mul, Conj, MulbyConj, CIS, Abs functions
- New "Enhanced Performance" mode EP Mode is for applications where math function inaccuracies don't dominate parameter inaccuracies (e.g., Monte Carlo simulations and Media applications)
- All VML functions are now threaded
- Optimized versions of the Cumulative Normal Distribution (CdfNorm), its inverse (CdfNormInv), and the inverse complementary error function (ErfcInv) have been added to the Vector Math Library.

User's Guide

- We have greatly improved our Intel MKL User's Guide. It is an indispensable tool for working with Intel MKL. Visit the Documentation page to download it or view it online.
- Compiler Support: Support for new compilers, including the new Intel® compilers 11.0 and PGI* compilers

Performance Improvements in Intel MKL10.2

- Further threading in BLAS level 1 and 2 functions for Intel® 64 architecture
  - Level 1 functions (vector-vector): (CS,ZD,S,D)ROT, (C,Z,S,D)COPY, and (C,Z,S,D)SWAP
    - » Increase in performance by up to 1.7-4.7 times over version 10.1 Update 1 on 4-core Intel Core i7 processors depending on data location in cache
    - » Increase in performance by up to 14-130 times over version 10.1 Update 1 on 24-core Intel® Xeon® processor 7400 series system, depending on data location in cache
  - Level 2 functions (matrix-vector): (C,Z,S,D)TRMV, (S,D)SYMV, (S,D) SYR, and (S,D)SYR2
    - » Increase in performance by up to 1.9-2.9 times over version 10.1 Update 1 on 4-core Intel Core i7 processor, depending on data location in cache
    - » Increase in performance by up to 16-40 times over version 10.1 Update 1 on 24-core Intel Xeon processor 7400 series system, depending on data location in cache
- Introduced recursive algorithm in 32-bit sequential version of DSYRK for up to 20% performance improvement on Intel Core i7 processors and Intel Xeon processors in 5300, 5400, and 7400 series.
- Improved LU factorization (DGETRF) by 25% over Intel MKL 10.1 Update 1 for large sizes on the Intel® Xeon® 7460 Processor; small sizes are also dramatically improved
- BLAS *TBMV/*TBSV functions now use level 1 BLAS functions to improve performance by up to 3% on Intel® Core™ i7 processors and up to 10% on Intel® Core™2 processor 5300 and 5400 series.
- Improved threading algorithms to increase DGEMM performance
  - Up to 7% improvement on 8 threads and up to 50% on 3,5,7 threads on the Intel Core i7 processor
  - Up to 50% improvement on 3 threads on Intel Xeon processor 7400 series
- Threaded 1-D complex-to-complex FFTs for non-prime sizes
- New algorithms for 3-D complex-to-complex transforms deliver better performance for small sizes (up to 64x64x64) on 1 or 2 threads
- Implemented high-level parallelization of out-of-core (OOC) PARDISO when operating on symmetric positive definite matrices
- Reduced memory use by PARDISO for both in-core and out-of-core on all matrix types
  - PARDISO OOC now uses less than half the memory previously used in Intel MKL 10.1 for real symmetric, complex Hermitian, or complex symmetric matrices.
- Parallelized reordering and symbolic factorization stage in PARDISO/DSS
- Up to 2 times better performance (30% improvement on average) on Intel Core i7 and Intel Core 2 processors for the following VML functions: v(s,d)Round, v(s,d)Inv, v(s,d)Div, v(s,d)Sqrt, v(s,d)Exp, v(s,d) Ln, v(s,d)Atan, v(s,d)Atan2
- Optimized versions of the following functions available for Intel® Advanced Vector Extensions (Intel® AVX)
  - BLAS: DGEMM
  - FFTs
  - VML: exp, log, and pow
  - See important information in the Intel® MKL User's Guide regarding the mkl_enable_instructions() function for access to these functions.

Performance Improvements in Intel MKL 10.1

We improved performance in all areas of the library. Below are some specific measured performance gains. Performance improvements are illustrated for each Intel MKL product domain (BLAS/LAPACK, FFT, VML, VSL, etc.)

- BLAS
- 32-bit improvements
  - Up to 50% improvement for (Z,C)GEMM on Quad-Core Intel Xeon processor 5300 series
  - 10% improvement for all (D,S,Z,C)GEMM code on Quad-Core Intel Xeon processor 5400 series
- 64-bit improvements
  - 50% improvement for SGEMM on the Intel Core i7 processor.
  - 30% improvement for right-side cases of DTRSM on the Intel Core i7 processor
- Direct sparse solver (DSS/PARDISO):
  - 35% performance improvement on average for out-of-core PARDISO
- VML and VSL
- Optimizations on the Intel® Core™ i7 processor :
  - Up to 17% improvement for the following VML functions: Asin, Asinh, Acos, Acosh, Atan, Atan2, Atanh, Cbrt, CIS, Cos, Cosh, Conj, Div, ErfInv, Exp, Hypot, Inv, InvCbrt, InvSqrt, Ln, Log10, MulByConj, Sin, SinCos, Sinh, Sqrt, Tanh
  - Up to 67% improvement for uniform random number generation
  - Up to 10% improvement for VSL distribution generators based on Wichmann-Hill, Sobol, and Niederreiter BRNGs (64-bit only)

Performance Improvements in Version 10.0

BLAS

- Threading of DGEMM was improved for small and middle sizes—outer product sizes by 10%, square sizes by 80%
- DGEMM/SGEMM large square and large outer product sizes were improved by 4-5% on 1 thread and 10-15% on 8 threads
- DTRSM, DTRMM, and DSYRK were improved by 5-30%
- Other level 3 real functions were improved by 2-4% on large sizes

LAPACK

- We dramatically improved the performance of several linear equation solvers (?spsv/?hpsv/?ppsv, ?pbsv/?gbsv, ?gtsv/?ptsv, ?sysv/?hesv). Banded and packed storage format and multiple right-hand sides cases see speed-ups of up to 100 times.
- All symmetric eigensolvers (?syev/?syev, ?syevd/?heevd, ?syevx/?heevx, ?syevr/?heevr) have significantly improved, since tridiagonalization routine (?sytrd/?hetrd) has sped up to 4 times.
- All symmetric eigensolvers in packed storage (?spev/?hpev, ?spevd/?hpevd, ?spevx/?hpevx) have significantly improved, since tridiagonalization routine in packed storage (?sptrd/?hptrd) has sped up to 3 times.
- Up to 2 times improvement for a number of routines applying orthogonal/unitary transformations (?ormqr/?unmqr, ?ormrq/?unmrq, ?ormql/?unmql, ?ormlq/?unmlq).

FFTs

- Improved single threaded performance of up to 1.8 times on complex 1D FFTs for power-of-two sizes
- On Intel® 64 architecture-based systems running in 64-bit mode single precision complex backward 1D FFT for data sizes greater than 2^22, elements have been sped up by up to 2 times on 4 threads and up to 2.4 times on 8 threads on Intel Itanium processors.

VML/VSL

- Performance of VSL functions is improved on non-Intel processors by approximately 2 times on average.
- Performance of VML vdExp, vdSin, and vdCos functions is improved on non-Intel processors by 18% on average.
- Performance of VSL functions is improved on IA-32 and Intel® 64 architecture by 7% on average.

Functionality

Linear Algebra: BLAS and LAPACK

Employ BLAS and LAPACK routines that are highly optimized for Intel processors, and that provide significant performance improvements over alternative implementations. Intel MKL 10.2 is compliant with the new 3.2 release of LAPACK.

The BLAS and LAPACK libraries are time-honored standards for solving a large variety of linear algebra problems. The Intel Math Kernel Library contains an implementation of BLAS and LAPACK that is highly optimized for Intel processors. Intel MKL can enable you to achieve significant performance improvements over alternative implementations of BLAS and LAPACK.

BLAS

Basic Linear Algebra Subprograms (BLAS) provide the basic vector and matrix operations underlying many linear algebra problems. Intel® MKL BLAS support includes:

- BLAS Level 1 - vector-vector operations
- BLAS Level 2 - vector-matrix operations
- BLAS Level 3 - matrix-matrix operations
- Sparse BLAS - an extension of BLAS Levels 1, 2, and 3

Multiple matrix storage schemes (Full, Packed, Banded) are provided for BLAS levels 2 and 3.

Gain the performance enhancements of multiprocessing without altering your application using parallelized (threaded) BLAS routines from Intel MKL. If you wish to manage threading in your applications, all BLAS functions within Intel MKL are thread-safe.

Sparse BLAS

Achieve performance improvements and lower memory requirements with sparse BLAS routines that have been carefully optimized for data sparsity. Sparse BLAS includes a set of functions that perform common vector and matrix operations on sparse data (data where the majority of elements are zero). Sparse BLAS coverage includes selected level 1, 2, and 3 BLAS routines for double-precision real functions. Sparse BLAS are often used in conjunction with sparse solvers. Intel MKL supports both NIST* and SparseKit* style interfaces.

The following Matrix Types and Data Storage Formats are supported:

Matrix Types	Data Storage Formats
General	Compressed Sparse Row (CSR)
Symmetric	Compressed Sparse Column (CSC)
Triangular	Block Sparse Row (BSR)
Diagonal	Diagonal (DIA)
Skew-symmetric	Coordinate (COO) Skyline

LAPACK

Intel MKL includes Linear Algebra Package (LAPACK) routines that are used for solving:

- Linear equations
- Eigenvalue problems
- Least squares problems
- Singular value problems

LAPACK routines support both real and complex data. Routines are supported for systems of equations with the following types of matrices: general, banded, symmetric or Hermitian, triangular, and tridiagonal. The LAPACK routines within Intel MKL provide multiple matrix storage schemes. LAPACK routines are available with a Fortran interface.

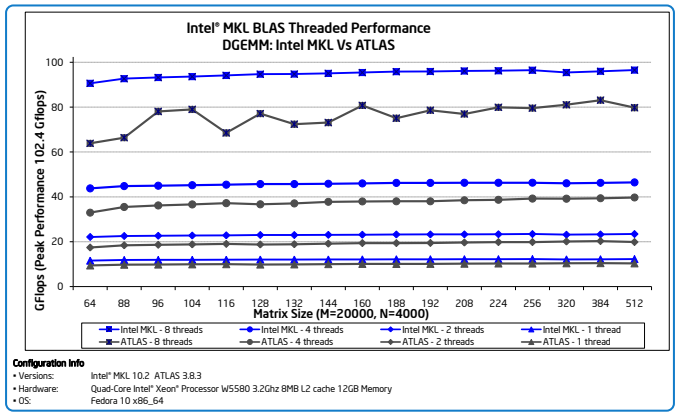
BLAS and LAPACK Performance

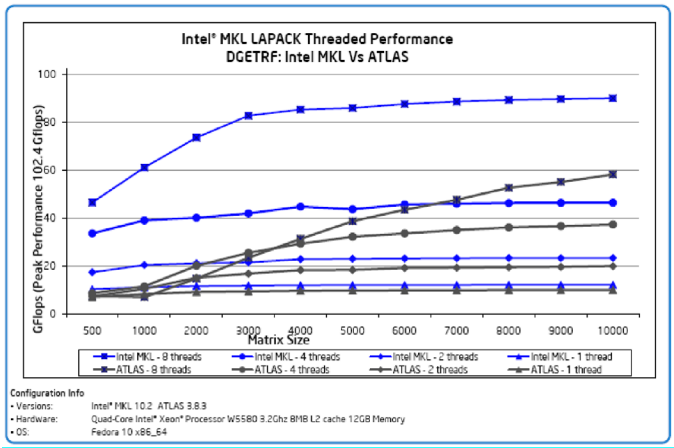
Double-precision general matrix-matrix multiply (DGEMM) is the workhorse routine for dense linear algebra. The charts below compare DGEMM performance of Intel MKL 10.2 to ATLAS* (Automatically Tuned Linear Algebra Software). ATLAS is a popular linear algebra software package that includes the complete BLAS API and a small subset of the LAPACK API. More information on ATLAS is available at http://math-atlas.sourceforge.net/.*

Intel MKL has been optimized for performance and tuned to provide excellent scaling for multiple threads. The performance benefits of using Intel MKL on today's dual and quad-core processors can be 2-5 times that of alternatives. The charts below show the following:

1. Intel MKL can provide significant performance benefit over ATLAS*.

2. The multiple processor/threading performance scaling of Intel MKL BLAS and LAPACK is impressive.





These charts show both the impressive scaling of Intel® MKL DGEMM and LAPACK (dgetrf) when using multiple threads as well as the performance advantage over ATLAS and FFTW respectively.

In summary, the BLAS and LAPACK functionality included in Intel MKL is highly optimized for Intel processors and can significantly increase the performance of your application compared to alternative implementations of BLAS and LAPACK.

Linear Algebra: ScaLAPACK

The Intel MKL implementation of ScaLAPACK can provide significant performance improvements over the standard NETLIB implementation.

Intel Math Kernel Library provides the underlying components of ScaLAPACK (Scalable Linear Algebra Package), including a distributed memory version of BLAS (PBLAS or Parallel BLAS) and a set of Basic Linear Algebra Communication Subprograms (BLACS) for interprocessor communication.

ScaLAPACK is a standard package of routines for solving linear algebra problems on distributed memory multiprocessor machines (clusters).

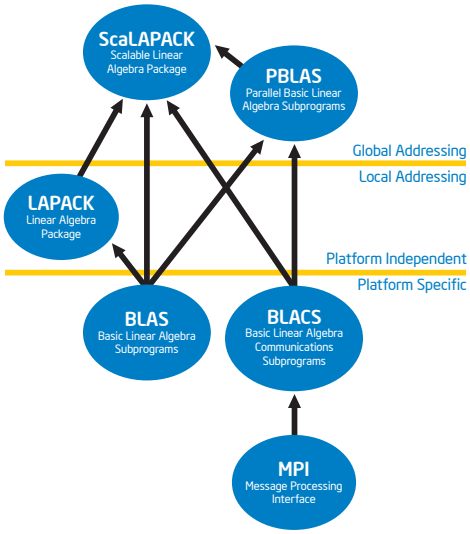


Figure 1: Relationship of ScaLAPACK and Components
*ScaLAPACK diagram, image courtesy of Innovative Computing Laboratory**

ScaLAPACK Performance

The Intel MKL implementation of the ScaLAPACK library is specially tuned for Intel Xeon, Intel Itanium, and Intel Pentium processor-based systems.

ScaLAPACK includes two areas of Linear Algebra—direct solvers and the eigenvalue problems. As such, we will look at both PDGETRF (a direct solver used for solving linear systems of equations) and PDSYEV (used for solving eigenvalue problems). PDGETRF (Parallel, Double precision, GEneral, TRiangular matrix Factorization) is a key function in the linear equations solver area because it is a general factorization routine that applies to many classes of matrices, and because the lower upper (LU) Factorization that it completes is the performance-intensive portion of linear equations solvers.

In our tests, we compare the Intel MKL implementation of ScaLAPACK to the publicly available implementation from NETLIB. We show the performance of Netlib ScaLAPACK using BLAS from Intel MKL as well as ATLAS*. More information on the ScaLAPACK library is available at http://www.netlib.org/scalapack/.*

Raw Performance

Figure 2 shows performance on a 32-node cluster with 64 Intel Xeon processors for various problem and memory sizes. Figure 2 illustrates that:

1. Intel MKL ScaLAPACK significantly outperforms NETLIB ScaLAPACK.
2. Intel MKL is even more impressive when compared to NETLIB ScaLAPACK using ATLAS* BLAS.

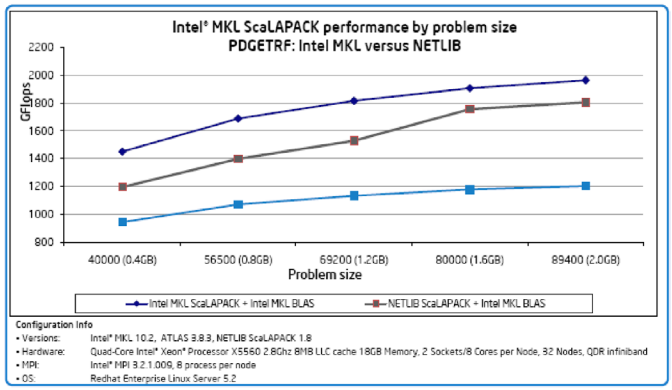


Figure 2: PDGETRF Performance Comparison Varying Problem Size

Because NETLIB ScaLAPACK requires users to link to an implementation of BLAS, the Intel MKL performance improvements from ScaLAPACK versus BLAS optimizations can be isolated and identified. A comparison of Intel MKL with NETLIB, where both are using Intel MKL BLAS, shows that the optimizations Intel has made specifically for ScaLAPACK constitute a 15 percent performance advantage over the NETLIB ScaLAPACK. The combined optimizations in Intel MKL ScaLAPACK and BLAS can deliver approximately 50% performance improvement overall when compared to NETLIB ScaLAPACK using ATLAS* BLAS.

In figure 3 below, we look at the PDSYEV, which computes eigenvalues and eigenvectors of a real symmetric matrix. Using the same 32-node (64 core) cluster of Intel Xeon processors we see how Intel MKL can deliver double the performance of NETLIB ScaLAPACK.

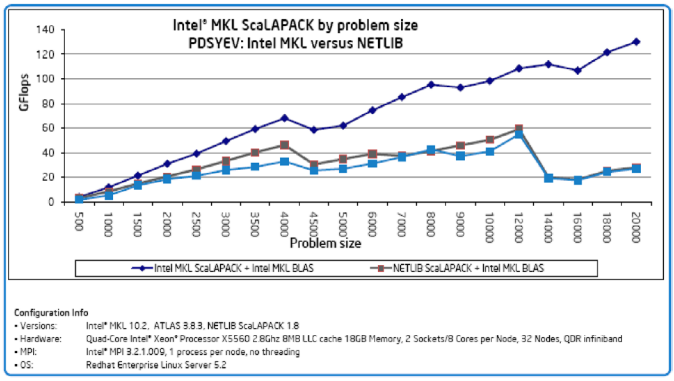


Figure 3: PDSYEV Performance Comparison Varying Problem Size

A major benefit of distributed memory parallel computing (clusters) is the ability to achieve parallel computing scales of very large magnitude. As such, users of clusters often have a particular interest in the ability of software to scale in performance along with the system size. The classic test is to increase the problem size proportionally with the increase in nodes and observe the extent to which the performance grows linearly. Figure 4 below displays this and shows that Intel MKL can provide tremendous gains over NETLIB using ATLAS BLAS on large systems.

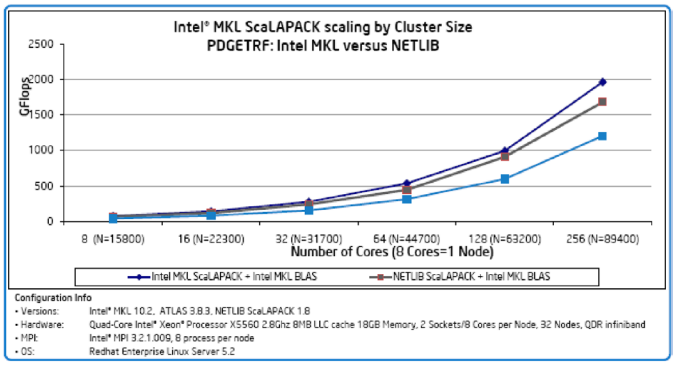


Figure 4: Performance Comparison Varying Cluster Size

Block Size Robustness

When running ScaLAPACK, you must decide how to "block" your data. The process of determining how to distribute your data among nodes involves choosing an appropriate block size. The block size determines the amount of data that goes to each node. This requires effort, and choosing the wrong block size can have significant adverse effects on performance.

The Intel MKL implementation of ScaLAPACK is tolerant of block size differences. Figure 5 below shows how Intel MKL provides approximately the same high performance regardless of block size. The same cannot be said for NETLIB ScaLAPACK.

In summary, the Intel MKL implementation of ScaLAPACK is highly optimized for Intel® processors and can significantly increase the performance of your application compared to other implementations of ScaLAPACK.

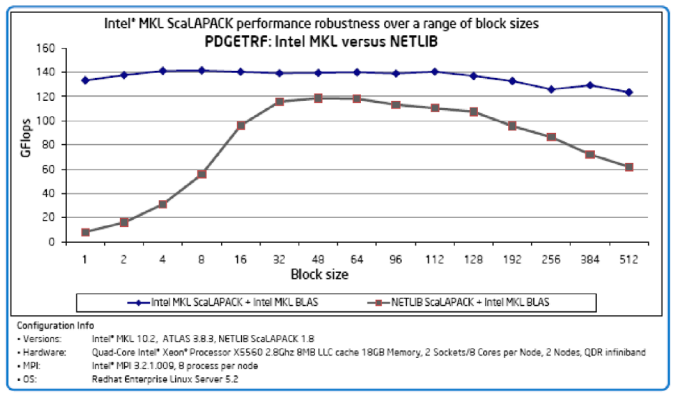


Figure 5: Performance Comparison Varying Block Size

References

ScaLAPACK Users Guide: Find a detailed description of ScaLAPACK usage made available by netlib.org at http://www.netlib.org/scalapack/slug/node1.html.

Linear Algebra: Sparse Solvers

Solve large, sparse linear systems of equations with the PARDISO Direct Sparse Solver—an easy-to-use, thread-safe, high-performance, and memory-efficient software library licensed from the University of Basel. Intel MKL also includes Conjugate Gradient and FGMRES iterative sparse solvers.

The Intel Math Kernel Library includes sparse solvers that use both direct and indirect/iterative methods.

		Intel® Math Kernel Library Sparse Solvers	
Matrix Types		Direct	Indirect/Iterative
General		PARDISO (d, z) (Parallel Direct Solver)	FGMRES (d)
Intel® Core™ processor family	Positive	PARDISO (d, z) (Parallel Direct Solver)	Conjugate Gradient (d)
	Indefinite	PARDISO (d, z) (Parallel Direct Solver)	

d: Supports double-precision data
z: Supports double-precision, complex data

PARDISO*: Parallel Direct Sparse Solver

New Out-of-Core Support!

In version 10.0 we added support for out-of-core memory to PARDISO. While computers have greatly increased memory capacity, there continue to be a large number of problems for which problem sizes are too great to solve with in-memory solutions. For customers who are encountering problem size limitations, we encourage you to try our new out-of-core memory PARDISO* solution.

The PARDISO* solver, licensed from the University of Basel, is a thread-safe, high-performance, memory-efficient software library for solving large sparse, symmetric, and asymmetric linear systems of equations on shared-memory multiprocessors.

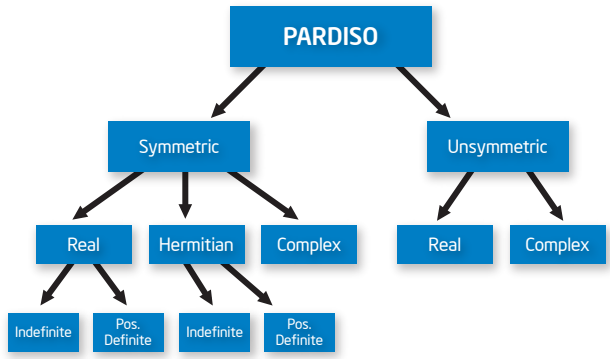
The PARDISO solver exploits pipelining parallelism and memory hierarchies with a combination of left- and right-looking level-3 BLAS super-node techniques. To improve sequential and parallel sparse numerical factorization performance, the algorithms are based on a level-3 BLAS update.

For sufficiently large problem sizes, numerical experiments demonstrate that the scalability of the parallel algorithm is nearly independent of the shared-memory multiprocessing architecture, and speedups of up to seven times (on eight processors) have been observed. This approach to parallelism is based on OpenMP directives.

The CCLRC (UK) has published a detailed analysis of direct sparse solvers in which PARDISO is found to perform very well compared to alternatives. View the report home page at http://epubs.cclrc.ac.uk/work-details?w=34126 or go directly to the .PDF file [401KB] at http://epubs.cclrc.ac.uk/bitstream/724/raltr-2005005.pdf.

Cranes Software has also published a paper on the use of Intel® MKL PARDISO in Finite Element Analysis applications. Download the .PDF file [187KB] at http://www.intel.com/cd/software/products/asmo-na/eng/371766.htm.

PARDISO supports a wide range of sparse matrix types and computes the solution of real or complex; symmetric, structurally symmetric, or asymmetric; positive definite, indefinite, or Hermitian sparse linear systems of equations on shared-memory multiprocessing architectures.



PARDISO Sparse Solver Matrices

Iterative Solvers

Intel MKL includes iterative sparse solvers that can be used to solve a general and symmetric positive-definite system of linear algebraic equations.

The solvers are based on a reverse communication interface (RCI) scheme that makes the user responsible for providing certain operations for the solver (for example, matrix-vector multiplications). This scheme gives the solvers great flexibility, as they are independent of the specific implementation of operations such as matrix-vector multiplication.

FGMRES Solver

FGMRES is a popular solver for solving a general sparse system of linear equations. The general applicability allows this solver to apply in a wide range of situations. The solver accounts for sparsity in the matrices, thereby enabling the solution of larger problem sizes than could be handled by a dense approach, as well as solving large sparse problems faster than a dense approach could.

Conjugate Gradient Solver

The Conjugate Gradient (CG) solver is suitable for the numerical solution of systems of linear equations represented by a matrix that is symmetric and positive definite. The conjugate gradient method is an iterative method, so it can be applied to sparse systems which are too large to be handled by direct methods. Such systems arise regularly when numerically solving partial differential equations. The CG solver is implemented in two versions: one for a system of equations with a single right-hand side, and another for systems of equations with multiple right-hand sides.

ILU0/ILUT Preconditioners

Preconditioners (also referred to as "accelerators") are used to accelerate an iterative solution process. In some cases, their use can reduce dramatically the number of iterations and thus lead to better solver performance. Intel MKL currently includes two preconditioners called ILU0 (Incomplete LU Factorization)and ILUT (Incomplete LU Factorization with Threshold). The ILU0/ILUT preconditioners can be applied to any nondegenerate matrix and can be used alone or together with the MKL FGMRES solver. Both preconditioners are based on a well-known factorization of the original matrix into a product of two triangular matrices (low triangular and upper triangular). Usually this decomposition leads to some fill-in in the resulting matrix structure as compared to the original matrix however the distinctive feature of the ILU0 preconditioner is that it preserves the structure of the original matrix in the result, while ILUT preconditioner controls the number of fill-ins. ILUT preconditioner is more reliable, while computations with ILU0 can normally be performed faster and with less memory usage.

Sparse BLAS

Sparse solvers are often used in conjunction with sparse BLAS. Sparse BLAS is a set of functions that perform a number of common vector and matrix operations on sparse data. Sparse vectors and matrices are those in which the majority of elements are zeros. Intel MKL includes an implementation of sparse BLAS that has been specially optimized to take advantage of data sparsity. Sparse BLAS coverage includes selected BLAS level 1 routines for all data types and level 2 and 3 BLAS routines for double-precision real functions. Matrix types include general matrices, symmetric matrices, triangular matrices, anti-symmetric, and diagonal matrices. Data structures supported include Compressed Sparse Row (CSR), Compressed Sparse Column (CSC), diagonal, coordinate, and skyline formats.

References

Linear Solver Basics (PDF 377KB): Find an overview of the terms and concepts associated with solutions to systems of linear equations at http://cache-www.intel.com/cd/00/00/22/97/229716_229716.pdf.

CCLRC Report on Direct Sparse Solvers (PDF 401KB): See a detailed comparison of the performance of many direct sparse solvers at http://epubs.cclrc.ac.uk/bitstream/724/raltr-2005005.pdf.

Utilization of Parallel Solver Libraries to Solve Structural and Fluid Problems (PDF 187KB): Read a whitepaper by Cranes Software that analyzes the ability of the Intel MKL PARDISO sparse solver in Finite Element Analysis (FEA) applications at http://www.intel.com/cd/software/products/asmo-na/eng/371766.htm.

Fast Fourier Transforms (FFT)

Utilize our multidimensional FFT routines (1D up to 7D) with a modern, easy-to-use C and Fortran interface. Intel MKL supports distributed memory clusters with the same API, enabling you to improve your performance by distributing the work over a large number of processors with minimal effort. Intel MKL also provides compatibility with the FFTW 2.x and 3.0 interfaces making it easy for current FFTW users to plug Intel MKL into their existing applications.

Fourier transforms are used in digital signal processing, image processing, and in partial differential equation (PDE) solvers. The Fast Fourier Transform (FFT) functionality in Intel Math Kernel Library has been highly optimized for Intel® architecture-based machines.

Intel MKL also provides support for distributed memory multiprocessor architecture machines (clusters).

Features of Intel® MKL Fast Fourier Transforms include:

- High performance
- Outstanding multiprocessor scaling
- Multidimension support (1-D up to 7-D)
- Mixed-radix support
- Modern, easy-to-use interface
- FFTW 2.x and 3.x interfaces

Interfaces

Fortran and C

Both Fortran and C interfaces exist for all FFT functions.

Modern FFT Interface

Intel MKL offers a novel FFT interface that is specifically designed to be easier to use and maintain.

FFTW Interface

Intel MKL includes FFTW 2.x and 3.x compatibility APIs, enabling FFTW users to integrate Intel® MKL with minimal effort. Our goal is to provide FFTW users with easy access to the high performance and quality of Intel MKL Fast Fourier Transforms. FFTW is an alternative FFT package from MIT. See the Technical User Notes at http://www.intel.com/software/products/mkl/docs/fftw_mkl_user_notes_2.htm.

- FFTW 3.x interface
- FFTW 2.x interface

Performance (Shared Memory Parallel)

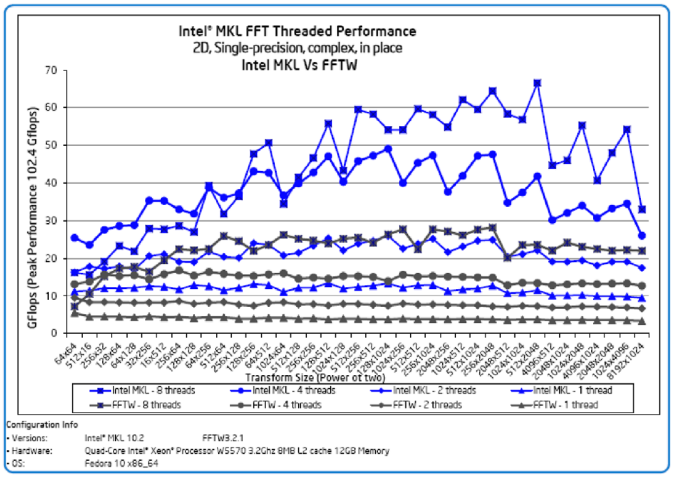
Intel MKL Fast Fourier Transforms are highly optimized for medium and large size transforms. The charts below compare the performance of Intel MKL with FFTW, a popular FFT software package. The charts illustrate these key points:

- Intel MKL offers outstanding performance for medium and large size transforms.
- Intel MKL offers outstanding scalability for multiprocessor systems.
- Intel MKL compares favorably to FFTW for medium and large size transforms.

Note: For all tests below, a fftw_plan_dft_xd() was called using the FFTW_PATIENT flag to ensure good performance was achieved for FFTW.

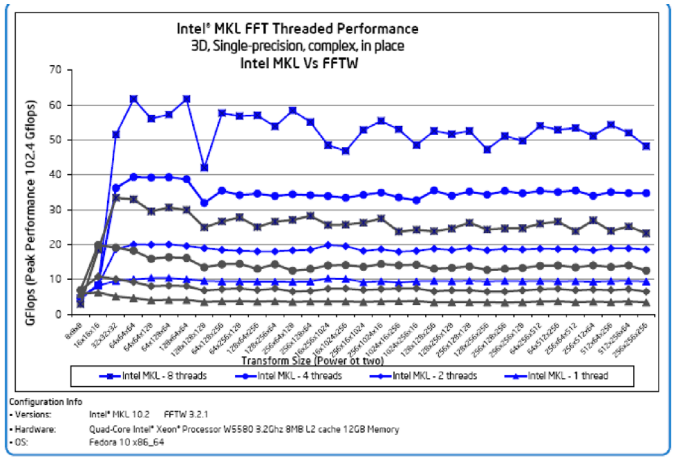
2-D Transforms

Two-dimensional transforms are large enough that they can benefit significantly from multiprocessing. The following charts illustrate how Intel MKL provides significantly better threaded performance than FFTW. In fact, Intel MKL single thread performance often outperforms the 2, 4, and 8 thread performance of FFTW.§



3-D Transforms

Three-dimensional transforms show the same behavior as the two-dimensional transforms. Intel MKL excels at providing excellent performance scaling for medium and large transforms.§

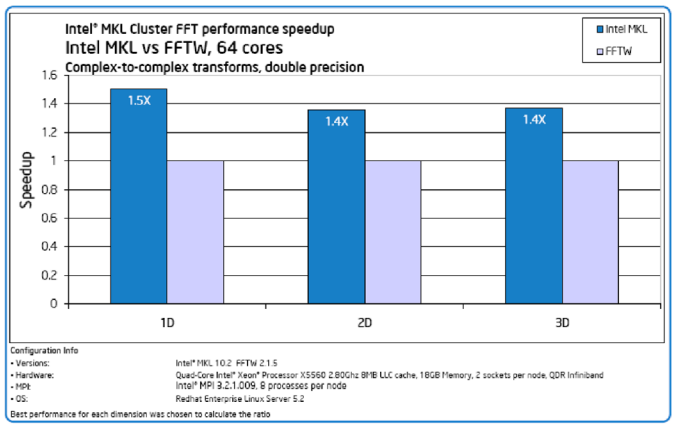


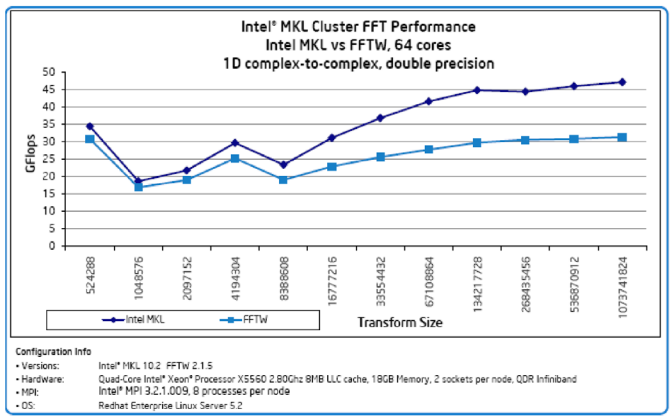
Performance (Distributed Memory)

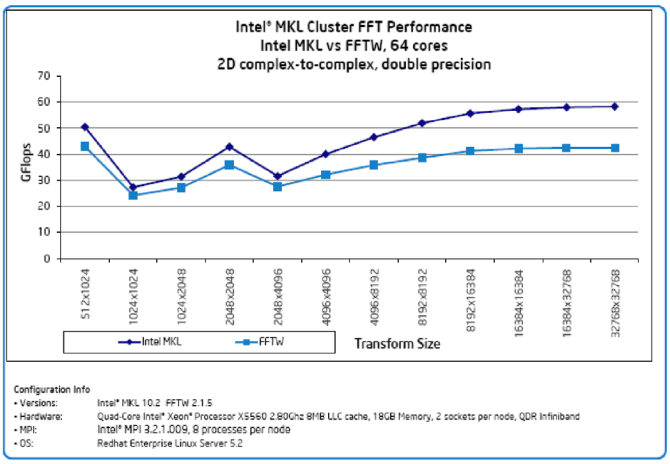
Intel MKL also provides support for distributed memory multiprocessor architecture machines (clusters). Included in this support are FFTs designed for distributed memory parallelism. As cluster systems are often configured with much higher degrees of parallelism than shared memory parallel systems, Intel MKL expands headroom for problem size and performance, particularly for large problems.

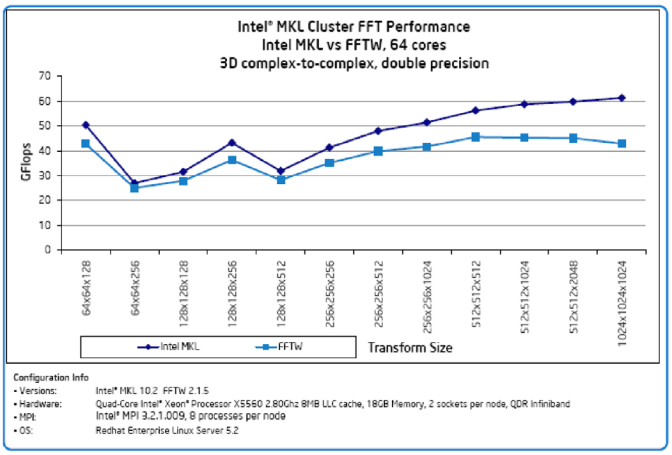
The charts illustrate these key points:

- Intel MKL offers outstanding performance across a wide range of transform sizes.
- Intel MKL offers increasing performance benefit over FFTW as the problem size increases.









In summary, the Fast Fourier Transform functionality of the Intel Math Kernel Library offers outstanding performance and scalability across a wide range of problem sizes that are of interest to the high performance computing community. Unlike FFTW, Intel MKL does not require the time-consuming process of doing preproduction machine calibration runs ("plan creation") prior to running one's software. Intel MKL provides FFT support for distributed memory parallel computing systems and provides outstanding performance headroom for larger problem sizes. Intel MKL includes a FFTW interface to enable developers to easily compare performance and switch from FFTW to Intel MKL with minimal source code changes.

References

FFTW 2.x Wrappers: Learn more about porting FFTW 2.x applications to Intel MKL at http://www.intel.com/software/products/mkl/docs/fftw2xmkl_notes.htm.

FFTW 3.x Wrappers: Learn more about porting FFTW 3.x applications to Intel MKL at http://www.intel.com/software/products/mkl/docs/fftw3xmkl_notes.htm.

API Comparison of Intel MKL vs. FFTW: View an article on mapping between the FFTW and Intel MKL Fast Fourier Transform APIs at http://www.intel.com/cd/ids/developer/asmo-na/eng/223902.htm?page=1.

Vector Math Library

Increase application performance with vectorized implementations of computationally intensive core mathematical functions (power, trigonometric, exponential, hyperbolic, logarithmic, and more).

The Vector Math Library (VML) included with Intel Math Kernel Library provides highly optimized vector implementations of computationally intensive core mathematical functions. The library has both Fortran and C interfaces for all VML functions. All functions have also been threaded (click on function to see threaded performance).

Supported VML Functions

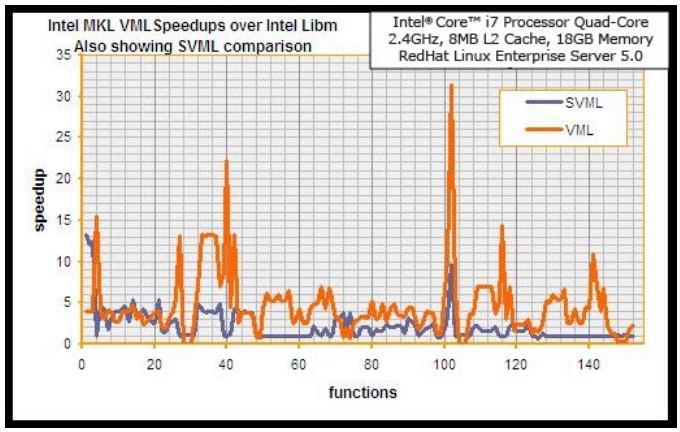
Arithmetic	Trigonometric	Hyperbolic	Power/Root
Add	Sin^	Sinh^	Pow^
Sub	Cos^	Cosh^	Powx^
Div	SinCos	Tanh^	Pow2o3
Sqr	CIS^^	Asinh^	Pow3o2
Mul	Tan^	Acosh^	Sqrt^
Conj^^	Asin^	Atanh^	Cbrt
MulByConj^^	Acos^		InvSqrt
Abs	Atan^		InvCbrt
	Atan2		Hypot
			Inv

Rounding	Exponential/ Logarithmic	Special	Other
Floor	Exp^	Erf	Inv
Ceil	Expm1	Erfc	Div
Round	Ln^	ErfInv	
Trunc	Log10^	ErfcInv (New)	
Rint	Log1p	CdfNorm (New)	
NearbyInt		CdfNormInv (New)	
Modf			

All functions are available for Real data types.
^ Indicates support for Complex data types.
^^ Indicates support for ONLY Complex data types.

Performance

The Vector Math Library in Intel MKL can provide substantial performance advantages over scalar implementations. The chart below compares Intel® MKL VML functions to the equivalent functions implemented by LibM and SVML, the runtime libraries that support calls to math functions from the Intel® C++ and Fortran compilers. The chart shows that most VML functions provide a 2-5x performance benefit in many cases and even up to 15x-30x in a few cases.



Accuracy Modes

VML functions support Single and Double Precision and are provided with three performance/accuracy modes. Having multiple accuracy modes is a key feature that separates Intel MKL from vectorizing compilers. With Intel MKL, you can choose the precision and accuracy that best meets your needs and thus maximizes performance of your specific code.

Vector Math Library Mode

	Single Precision	Double Precision
High Accuracy	Math function inaccuracies don't dominate parameter inaccuracies	Rigorous Accuracy
Low Accuracy		Most Applications
Enhanced Performance	Media Applications	Math function inaccuracies don't dominate parameter inaccuracies

See detailed VML Performance and Accuracy tables of all functions on various Intel® processor-based systems at http://www.intel.com/software/products/mkl/data/vml/vmldata.htm.

In summary, use the Vector Math Library in Intel MKL to ensure you get maximum performance instead of relying on your compiler to vectorize your code. The Intel® MKL Vector Math Library gives you more control and can massively increase the performance of your application compared to nonvectorized scalar functions from compiler runtime libraries.

References

Intel® VML Performance and Accuracy: Find detailed information on performance and accuracy of Intel MKL Vector Math Library (VML) on various Intel processors at http://www.intel.com/software/products/mkl/data/vml/vmldata.htm.

Vector Statistical Library

The Intel Math Kernel library includes an expanding amount of statistical functionality that we aggregate into a sub-library, which we call the Vector Statistical Library (VSL). The Intel® MKL Vector Statistical Library today includes Convolution/Correlation and an extensive collection of random number generators.

Convolution/Correlation

VSL provides a set of routines intended to perform linear convolution and correlation transformations for single and double precision data. We provide:

- Fourier and Direct Algorithms
- One or Multiple Dimensions
- Single and Double Precision
- C and Fortran Interfaces
- Modern Easy-to-Use "Task"-oriented API
- IBM ESSL* Interface for ESSL Users

Detailed information on the Convolution and Correlation routines in the Intel MKL Vector Statistical Library can be found in the Intel MKL Reference Manual at http://www.intel.com/software/products/mkl/docs/WebHelp/mkl.htm.

Random Numbers

Speed up your simulations using our vector random number generators, which can provide substantial performance improvements over scalar random number generator alternatives.

The Intel MKL Vector Statistical Library (VSL) contains a collection of random number generators for a number of probability distributions. All VSL functions are highly optimized to deliver outstanding performance on Intel® architecture.

Applications that can significantly improve performance with VSL include simulation algorithms commonly used in physics, chemistry, medical simulations, and financial analysis software. The library provides both Fortran and C interfaces for all VSL functions.

VSL provides nine basic random number generators that differ in speed and statistical qualities, as shown below.

Basic Random-Number Generators (BRNGs)

Pseudo-random	
MCG59	Multiplicative Congruential Generator 59-bit
MCG31m1	Multiplicative Congruential Generator 31-bit
MRG32k3a	Multiple Recursive Generator 32-bit
R250	Generalized feedback shift register
Wichman-Hill	A set of 273 basic generators
MT19937	Mersenne Twister
MT2203	A set of 1024 Mersenne Twister basic generators
Quasi-random	
Sobol	A 32-bit Gray code-based generator
Niederreiter	A 32-bit Gray code-based generator

VSL supports multiple methods for creating random streams, including the leapfrog method and the block-splitting method. For large Monte Carlo simulations, VSL provides routines to save or restore random streams to or from a file. The abstract streams give greater flexibility in the use of distribution generators with random data stored in a buffer.

VSL also provides support for user-designed basic generators, as well as for numerous continuous and discrete distribution generators.

Distribution Generator Types

Continuous	Discrete
Uniform	Uniform
Gaussian	UniformBits
GaussianMV	Bernoulli
Exponential	Geometric
Laplace	Binomial
Weibull	Hypergeometric
Cauchy	Poisson
Rayleigh	Poisson with varying mean
Lognormal	Negative binomial
Gumbel	—
Gamma	—
Beta	—

Random Number Generator Performance

VSL functions operate on single- and double-precision real vector arguments and can provide substantial performance advantages over scalar implementations. Tables containing complete performance information for all VSL random number generators and distributions on Intel processors are available here.

To demonstrate the optimized performance of Intel Math Kernel Library, we compared the standard C rand() function to the Intel MKL vector uniform random number generator. Intel MKL VSL functions are thread-safe, so we also present the speed of the Intel® MKL vector uniform random number generator after it has been parallelized using OpenMP.

VSL Performance vs. C Code on Intel® Xeon® Processor-based System[2]

Intel Xeon Processor[1]	Running Time (seconds)	Speedup vs. rand() (times)
Standard C rand() function	40.52	1.00
Intel® MKL VSL random number generator	6.88	5.89
OpenMP* version (8 threads)	0.92	44.04

1. Two-way Quad-Core Intel® Xeon® processor-based system (8 cores total), running at 2.4 GHz with 2x8MB L2 cache and 4GB memory with Windows* 2003 Enterprise x64 Edition and Intel® C++ Compiler 10.0
2. Intel® 64 architecture version of Intel® MKL VSL was used in measurements

Comparison of Intel MKL to Alternative Libraries

Visual Numerics Inc. and Numerical Algorithms Group Ltd. are providers of popular numerical and statistical libraries. Visual Numerics provides a collection of mathematical and statistical analysis subroutines for Fortran and C/C++ users known as the IMSL Fortran 90 MP Library (F90MP*) and the IMSL C Numerical Library*, respectively. Numerical Algorithms Group provides numerical libraries for C/C++ and Fortran users known as NAG Fortran 77 Library*, NAG Fortran 90 Library*, NAG C Library*, NAG SMP Library*, and the NAG Parallel Library*.

The following table presents summary information on random number generation capabilities existing in the Intel MKL 10.2, IMSL F90MP 6.0, and NAG Fortran 77 (Mark 21) libraries.

Intel® Math Kernel Library (Intel® MKL) 10.2 Features vs. IMSL* and NAG*

Feature	Intel MKL	IMSL	NAG
BRNGs	7 pseudorandom 2 quasi-random	9 pseudorandom 1 quasi-random	2 pseudorandom 3 quasi-random
User-designed BRNGs	Supported	User-designed BRNG replaces library BRNGs; many library services do not work with user-designed BRNG	Not supported
Sequence manipulation	▪ Mechanisms of creating, copying and deleting streams ▪ Saving/restoring stream to/from a file ▪ Arbitrary number of random streams based on one or more BRNGs	▪ Service subroutines for switching between BRNGs ▪ Subroutines for saving and restoring BRNG seed ▪ Subroutines for saving and restoring state tables for GFSR and shuffled BRNGs	▪ Subroutines for saving and restoring BRNG seed ▪ Service subroutines for switching between BRNGs
Sub-sequence splitting	▪ Support for both "skip-ahead" and "leapfrog" methods ▪ Skip-ahead method allows skipping an arbitrary number of elements in a sequence ▪ Leapfrog method allows splitting into an arbitrary number of non-overlapping subsequences	Limited skip-ahead method support (only skipping 100,000 elements in a sequence)	Not supported
Distribution generators and other BRNG-related functionality	▪ 20 univariate ▪ 1 multivariate ▪ Multiple transformation methods available by passing method ID as parameter	▪ 24 univariate ▪ 3 multivariate ▪ General discrete, continuous univariate and data based multivariate generators ▪ Random orthogonal and correlation matrices, two-way tables, order statistics, samples and permutations, stochastic processes ▪ Multiple transformation methods available as separate subroutines ▪ ORNGs are for uniform distribution only	▪ 24 univariate ▪ 2 multivariate ▪ General univariate distribution generator ▪ Random samples, permutations, time-series models, orthogonal and correlation matrices, random tables ▪ Multiple transformation methods are not available ▪ ORNGs are for uniform, Gaussian and lognormal distributions
Vector/scalar interface	Vector interface only	Some distribution generators have vector and scalar form; others are of either vector or scalar form only	Some distribution generators have vector and scalar form; others are of either vector or scalar form only
Programming languages interface	C and Fortran interface in a single package	Fortran, C and Java* interface in separate packages	C and Fortran interface in separate packages
Supported hardware	▪ Intel® architectures only ▪ Highly optimized for target architecture	Multiple platforms (e.g., Intel, Cray, HP, IBM, Sun)	Multiple platforms (e.g., Apple, Cray, HP, IBM, Sun)

Two methods for generation of normally distributed random numbers are available in the library starting from Mark 20.

The following table presents numerical and performance results on an Intel Xeon processor-based system for the three libraries with random number generation capabilities, namely for Intel MKL 10.2, IMSL F90MP 6.0, and NAG SMP Fortran 77 Library (Mark 21). Speedups are measured against the slowest version.

Performance Comparison: Black-Scholes Option-Pricing Model[1, §]

Library	Basic Generator	Option Value (Exact Value)		Absolute Error (Standard Error)		Time (seconds)	Speedup (times faster)
		Call	Put	Call	Put		
Intel® MKL	MCG31m1	16.7306 (16.7341)	7.2177 (7.2179)	0.0036 (0.0019)	0.0002 (0.0009)	4.671	8.78
	MCG59	16.7364 (16.7341)	7.2162 (7.2179)	0.0023 (0.0019)	0.0017 (0.0009)	4.86	8.44
	MT19937	16.7349 (16.7341)	7.2164 (7.2179)	0.0007 (0.0019)	0.0015 (0.0009)	5.078	8.08
NAG	Original	16.7339 (16.7341)	7.2182 (7.2179)	0.0002 (0.0019)	0.0003 (0.0009)	11.45	3.58
IMSL	MT19937	16.7324 (16.7341)	7.2178 (7.2179)	0.0017 (0.0019)	0.0001 (0.0009)	35.703	1.15
	Minimal Standard	16.7343 (16.7341)	7.217 (7.2179)	0.0001 (0.0019)	0.0009 (0.0009)	41.031	1.00

1. Monte Carlo is a valuable tool for performing real-time financial analysis of complex, worldwide markets. In our example, we consider the well-known Black-Scholes option-pricing model, which is a framework for thinking about option pricing and is a de facto standard in the financial world.

We used the "minimal standard" and 32-bit MT19937 basic generators in the IMSL library. We used the "original" basic generator in the NAG library. For Intel MKL 10.0, we used three basic generators: MCG31m1, MT19937, and MCG59. The last being identical to the "original" basic generator in NAG libraries, while properties of MCG31m1 are similar to the "minimal standard" basic generator from IMSL.

For more information on this performance test, please refer to the white paper *Making the Monte Carlo Approach Even Easier and Faster* by Sergey A. Maidanov and Andrey Naraikin at: http://www.intel.com/cd/ids/developer/asmo-na/eng/95573.htm.

In summary, the Vector Statistical Library of Intel Math Kernel Library contains Convolution/Correlation and a comprehensive set of random number generators that are highly optimized for Intel architecture and can significantly increase the performance of your application over alternative solutions.

References

Intel VSL Performance Data: Find complete performance information for all Intel VSL random number generators and distributions on Intel Xeon and Intel Itanium processors at http://www.intel.com/software/products/mkl/data/vsl/vsl_performance_data.htm.

Intel VSL Notes (PDF 1.2MB): View detailed information on VSL BRNGs and distributions, and random number generators in general at http://www.intel.com/cd/software/products/asmo-na/eng/347649.htm.

Monte Carlo European Options Pricing (PDF 85KB): See a paper discussing the use of popular random number generators in derivative security pricing at http://software.intel.com/en-us/articles/monte-carlo-simulation-using-various-industry-library-solutions.

LINPACK Benchmark

Intel provides free LINPACK benchmark packages built with Intel MKL to help you obtain the highest possible benchmark results for your Intel architecture-based systems.

Intel® Optimized LINPACK Benchmark packages can help you in your quest to obtain the highest possible benchmark results for Intel architecture-based systems. These free packages are implementations of the LINPACK benchmarks, which use BLAS and LAPACK software that has been highly tuned for maximum performance on Intel Xeon processor-based and Itanium-based systems. These same high performance BLAS and LAPACK routines are available to software developers in the Intel Math Kernel Library.

Intel offers two LINPACK benchmark packages:

Intel® Optimized SMP LINPACK Benchmark package

For use on SMP machines. This package contains implementations of the LINPACK 1000 benchmark code* (http://www.netlib.org/benchmark/1000d). See below for performance and download information.

The package includes the executables listed below, as well as shell scripts and input files.

Intel® Optimized (SMP) LINPACK Benchmark 10.2

File Name	Description
linpack_itanium	64-bit program executable for Itanium®-based systems.
linpack_xeon32	32-bit program executable for Intel® Xeon® processor-based systems.
linpack_xeon64	64-bit program executable for 64-bit Intel® Xeon® processor-based systems.

Intel® Optimized MP LINPACK Benchmark for Clusters package

This package is an implementation of the Massively Parallel MP LINPACK* (http://www.top500.org/) benchmark for use on distributed memory computer systems (clusters). Use this package to benchmark your computer cluster for submission to the Top 500 Supercomputers list.

Intel® Optimized MP LINPACK Benchmark 10.2 for Clusters

File Name	Description
HPL 1.0a	The complete HPL 1.0a distribution, as well as additional files to make HPL easier to use.
nodeperf.c	A program to test for DGEMM performance consistency on all cluster nodes.

Ease of Use

The Intel Optimized LINPACK benchmark packages have been designed to save you time. Fewer file downloads, no need to compile, and less iterating are benefits that save your valuable time. The Intel Optimized SMP LINPACK benchmark package doesn't require any of the time-consuming searching that HPL does, and while the Intel Optimized MP LINPACK benchmark package does do searching, it provides information early in the process so you don't have to wait until the entire run is completed before reconfiguring and beginning another run. Try the Intel Optimized LINPACK benchmark packages and see how much time you save.

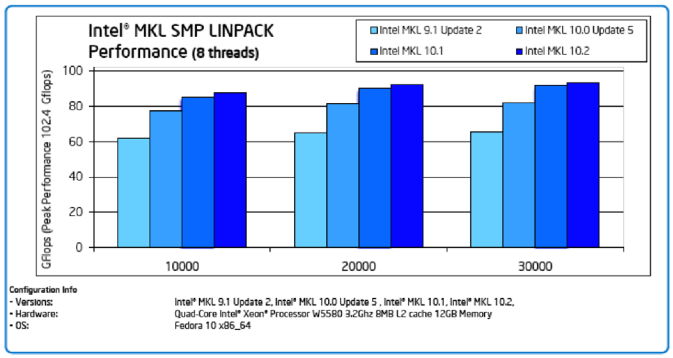
See the LINPACK benchmark chapter of the Intel® MKL Users Guide for more information.

Elapsed Time h:mm	Intel® Optimized SMP LINPACK binary	**Elapsed Time h:mm**	HPL
0:00	Start	0:00	Start
0:00	Download Intel Optimized LINPACK package	0:00	Download HPL
0:10	Configure scripts	0:10	Download BLAS
0:20	Start Run	0:20	Download MPI
1:00	Collect Results	0:30	Build MPI
		1:00	Build HPL
		1:30	Start Run 1
		2:30	Review Results
		2:50	Change HPL.dat for improvements
		3:00	Start Run 2
		4:00	Review Results
			Iterate changing HPL.dat and running until satisfied with results. Can take many iterations.
		8:00	Call it a day and vow to finish tomorrow...

Performance

The following charts show the impressive performance that the Intel Optimized SMP LINPACK Benchmark package has achieved:

- 91.5 percent of theoretical maximum performance on Quad-Core Intel Xeon processor based systems.
- Improved performance with newer versions of Intel MKL, up to 43% better performance with MKL 10.2 compared to MKL 9.1



Downloads

The Optimized LINPACK and MP LINPACK benchmark packages listed below are available for free download.

Download now at http://www.intel.com/cd/software/products/asmo-na/eng/363191.htm

Package	Download Size	Package Contents: Intel® Optimized LINPACK Benchmark – Source	Package Contents: Intel® Optimized LINPACK Benchmark – Binary	Package Contents: Intel® Optimized MP LINPACK Benchmark for Clusters – Source	Package Contents: Intel® Optimized MP LINPACK Benchmark for Clusters – Binary
Linux* package (.tgz)	6.71MB		X	X	X
Windows* package (.zip)	3.79MB		X	X	X
Mac OS* package (.tgz)	763KB		X		

Questions/Comments?

Do you have feedback on the LINPACK benchmark? You can post a comment at the Intel MKL user forum at http://softwarecommunity.intel.com/isn/Community/en-US/forums/1273/ShowForum.aspx

References

Intel® Cluster Tools: http://www.intel.com/cd/software/products/asmo-na/eng/cluster/244171.htm

Compatibility

Operating Systems

Intel MKL 10.2 supports Linux*, Windows* (including HPC Server 2008) and Mac OS* X. Linux variants include: Red Hat*, Suse*, Debian*, Ubuntu*, Asianux*, and other Linux Standard Base 3.1 variants.

Development Environments

Intel MKL is easily used and integrated with popular development tools and environments, such as Microsoft Visual Studio*, Xcode*, Eclipse*, and the GNU Compiler Collection (GCC).

Processors

Intel MKL 10.2 supports all Intel Architecture compatible processors and is specifically optimized for:

- Intel Xeon processor family
- Intel Core processor family
- Intel Itanium processors family
- Intel Pentium processor family
- AMD Opteron* and Athlon* processor families

NOTE: Intel MKL for Mac OS X is not available as a standalone product. It is only available with the Intel C++ Compiler Professional Edition and Intel Fortran Compiler Professional Edition.*

Technical Support

Every purchase of an Intel® Software Development Product includes a year of support services, which provides access to Intel® Premier Support and all product updates during that time. Intel Premier Support gives you online access to Intel MKL discussion forum, technical notes, application notes, and documentation. Install the product, and then register to get support and product update information.

Intel® Premier Support

Receive one year of world-class technical support with every purchase of Intel MKL. During this period, you can download product upgrades free of charge, including major version releases. For more information, visit the Intel Registration Center at https://registrationcenter.intel.com/RegCenter/Register.aspx. Additionally, the user forum is a great place to get community support.

User Forum

Share experiences with other users of Intel MKL at the Intel moderated Intel MKL Discussion Forum at: http://softwarecommunity.intel.com/isn/Community/en-US/forums/1273/ShowForum.aspx

References

See all of the documentation available for Intel MKL at http://www.intel.com/cd/software/products/asmo-na/eng/345631.htm

§. Performance tests and ratings are measured using specific computer systems and/or components and reflect the appropriate performance of Intel products as measured by those tests. Any difference in system design or configuration may affect actual performance. Buyers should consult other sources of information to evaluate the performance of systems or components they are considering purchasing. For more information on performance tests and on the performance of Intel products, go to http://www.intel.com/software/products/

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