PerfMPL®

What is this?

A Technical overview of PerfMPL®

(Math Performance Library)

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Introduce

As the software closest to the hardware, the mathematical function library is the guarantee for the full use of hardware computing power, and it is also the only bridge between hardware and applications. Therefore, mathematical function libraries have always played an important role in various fields such as scientific computing, engineering computing, and AI computing. In the past and in the future, with the continuous development of computer architecture, continuous breakthroughs in cutting-edge technology exploration, and continuous expansion of application fields, the optimization of mathematical function libraries in the entire computing technology industry has never stopped. With the rise of heterogeneous computing and diversified computing power, a high-performance mathematical function library that can be ported across platforms will become more and more important in the field of computing technology.

This document is intended to provide an introductory technical overview of the mathematical function library PerfMPL® developed by PerfXLab

What is PerfMPL

PerfMPL®（Math Performance Library）is a set of extremely optimized mathematical calculation libraries for various instruction set processors of computers and applications in various fields. PerfMPL® has its own powerful package management capabilities, so it can be used as the basic software of the general mathematical function library for instruction set CPU platforms such as x86, ARM, and RISC-V, and can also be used as various types of DSA acceleration hardware to meet the needs of various application scenarios The basic software supported will eventually become a dependent mathematical computing library for

applications in various fields (such as: AI, CAE, EDA, signal processing, etc.).

Legal Information

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Introduction to Mathematical Function Library

Galileo once said: "Mathematics is a language, the common language of all sciences; the universe unfolded in front of our eyes is like a big book written in mathematical language. If you don't master the language of mathematical symbols, you will be in a dark maze." Wandering around, knowing nothing clearly."

The mathematical function library is specially designed for computing applications in the fields of science, engineering, big data and finance

that require guaranteed calculation accuracy and pursuit of ultimate performance.

Introduction to PerfMPL

Xianyi Zhang (Ph.D., Chinese Academy of Sciences) initiated the OpenBLAS open source project in 2011. OpenBLAS is an optimized BLAS library (http://www.openblas.net), which is widely used in scientific computing, data analysis, deep learning algorithms, artificial intelligence And other fields, it is integrated by well-known projects such as Caffe, MXNet, Julia, Ubuntu, Debian, openSUSE, GNU Octave; OpenBLAS is also used as one of the basic software of various processor system development kits.

PerfMPL is based on OpenBLAS. After years of development, it has gradually covered FFT (Fast Fourier Transform), SPARSE (Sparse Matrix Computing Library), MATH (Basic Math Library), VML (Vector Math Library), DNN (Deep Neural Networks deep neural network), PerfIPP (image processing, etc.) and other computing libraries.

PerfMPL is based on the accumulation of unified mathematical function library technology with independent intellectual property rights of PerfXLab. Through targeted optimization, improvement, and tailoring, it has developed two branch versions:

1. PerfMPL for general computing power, mainly for CPU instruction sets.
2. PerfMPL for dedicated computing power, mainly for GPU, NPU, ASIC, FPGA and various DSA.

Generally speaking, because the architecture of the CPU determines its strong computational versatility, the "PerfMPL for general computing power" software release version supports the most comprehensive mathematical library. The following takes this version as an example to introduce all the core function libraries included in PerfMPL.

No.	Library Name	Describe	Applicable Scene
1	OpenBLAS / PerfBLAS	Basic Linear Algebra Subprograms LAPACK module	Vector-Vector Operations Vector-Matrix Operations Matrix-matrix operations Solving Dense Linear Equations Eigenvalue solving
2	PerfFFT	Fast Fourier Transform (Fast Fourier Transform) operation library is a method for quickly calculating the discrete Fourier transform (DFT) of a sequence or its inverse transform. It is widely used in the fields of engineering, science and mathematics. The complexity is reduced from O(n2) to O(n log n)	C2C, C2R, R2C, R2R forward and reverse transformation of FFT Support any scale Support 1D, 2D, 3D
3	VML	Vector Mathematical Library (Vector Mathematical Library), through SIMD instruction optimization, inline assembly and other methods, vectorizes the input data, gives full play to the register characteristics of the accelerated instruction set, and realizes the performance improvement of each platform.	Mathematical operations on vectors, including power functions, trigonometric functions, exponential functions, hyperbolic functions, logarithmic

			functions, etc.
4	MATH	The basic arithmetic mathematics library achieves performance improvement through periodic function specification and algorithm improvement, and is suitable for various processors.	Basic mathematical operations, including trigonometric, logarithmic, exponential, and power functions
5	SPARSE	Sparse iterative solution library (Iterative Sparse Solvers), including preconditioned conjugate gradient method (PCG) and generalized conjugate residual method (GCR), etc.	Sparse symmetric positive definite matrix, sparse general matrix linear equations iterative solution.
6	PerfIPP	Support common image filtering, color space transformation, etc.	Common functions for image and signal processing
7	PerfDNN	Deep learning operator library, including inference and training operators	Deep Learning Inference and Training

Note: The main programming languages of PerfMPL are C/C++ and Assemble, and some PerfMPL function libraries have Fortran interface; it supports various operating system platforms such as Linux, Windows, OSX/MacOS.

PrefXLab's software accelerated computing theoretical system is: model guidance, algorithm support, optimization support, performance is king, specifically for PerfMPL:

The main optimization strategies of PerfMPL are as follows

- Performance-driven optimization model building technology

- New parallel algorithm design for complex architecture
- Template-based high-performance assembly code automatic generation technology
- Adaptive performance optimization technology with both scenario and application awareness

PerfMPL for General Computing Power

The "PerfMPL for general computing power" version mainly refers to the mathematical acceleration computing library for CPU (Central Processing Unit, central processing unit). Some function libraries of PerfMPL (such as OpenBLAS) have fully supported mainstream ISA (instruction set architecture) x86, ARM, MIPS, Power, LoongArch, RISC-V and Alpha, etc.

The goal of "PerfMPL for general computing power" is to provide the most comprehensive support, better performance and calculation accuracy guarantee for mainstream CPUs in the market in terms of core math libraries, and gradually form multiple branch versions such as PerfMPL for x86 and PerfMPL for ARM. PerfMPL appears under the name of RVCL® (RISC-V Computing Library) in the RISC-V instruction set architecture.

The optimization driving force of PerfMPL mainly comes from two aspects: 1) The upgrade iteration of the processor architecture. 2) Application requirements brought by new scenarios and new algorithms. The following is a diagram of the interaction between PerfMPL and processor architecture and application requirements:

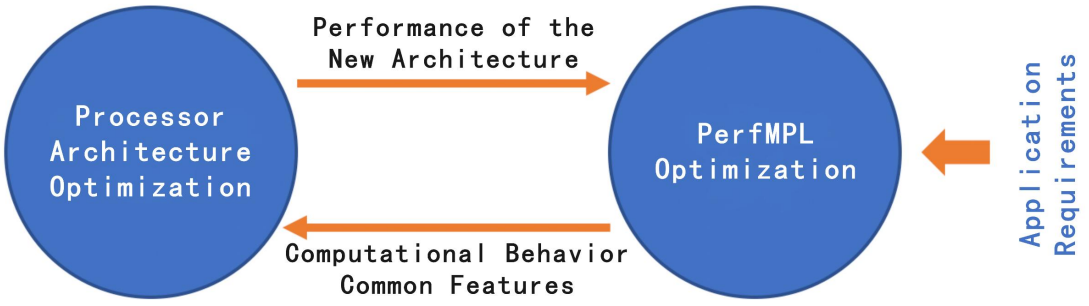


Figure 1

The following is a schematic diagram of the location of PerfMPL (mathematics library) in the general computing power software stack:

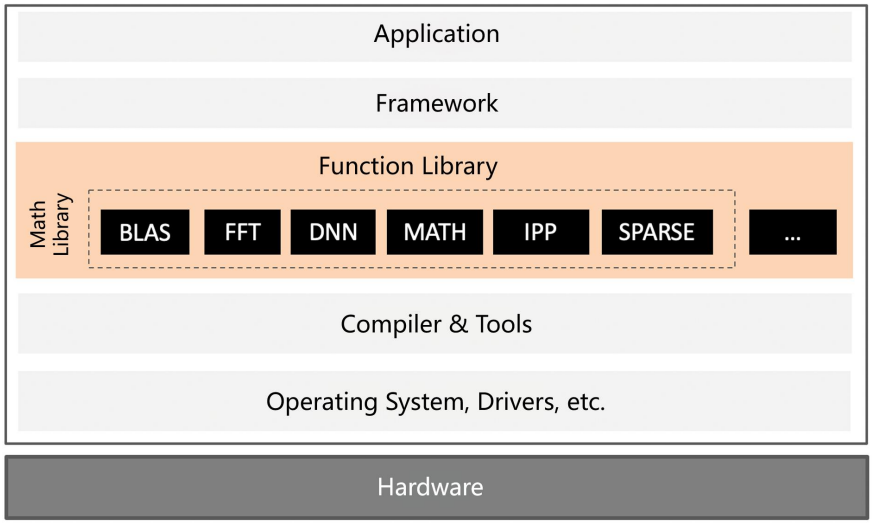


Figure 2

To illustrate the performance of PerfMPL optimized for the processor, some test data are shown below.

1. DGEMM_NN

Hardware Environment: Kunpeng 920 2.6GHz

Compare Software: PerfMPL, 1.0.0
OpenBLAS, 0.3.13
ARMPL, 21.0
Eigen, 0.1.3
BLIS, 0.81

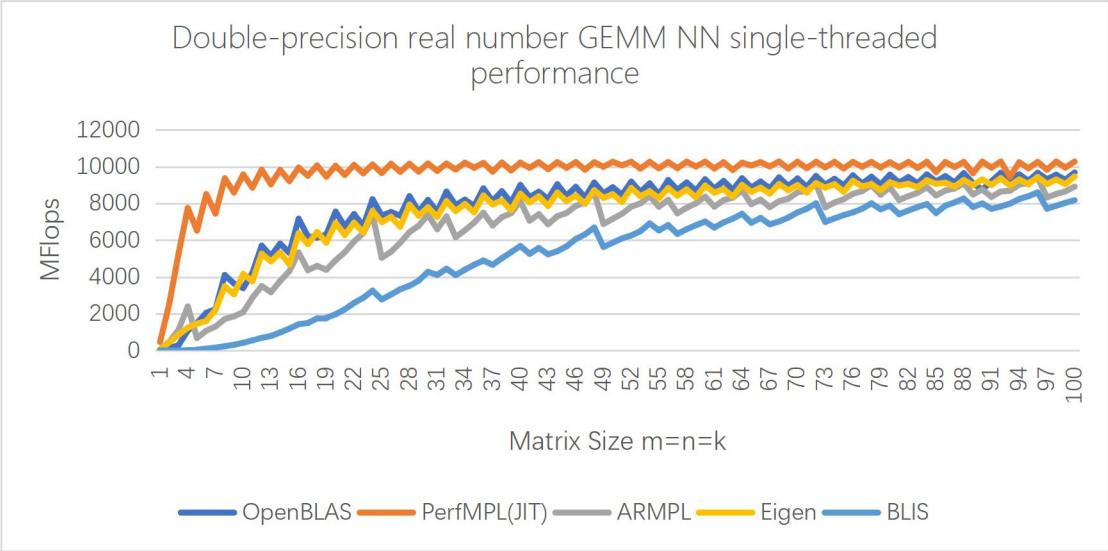
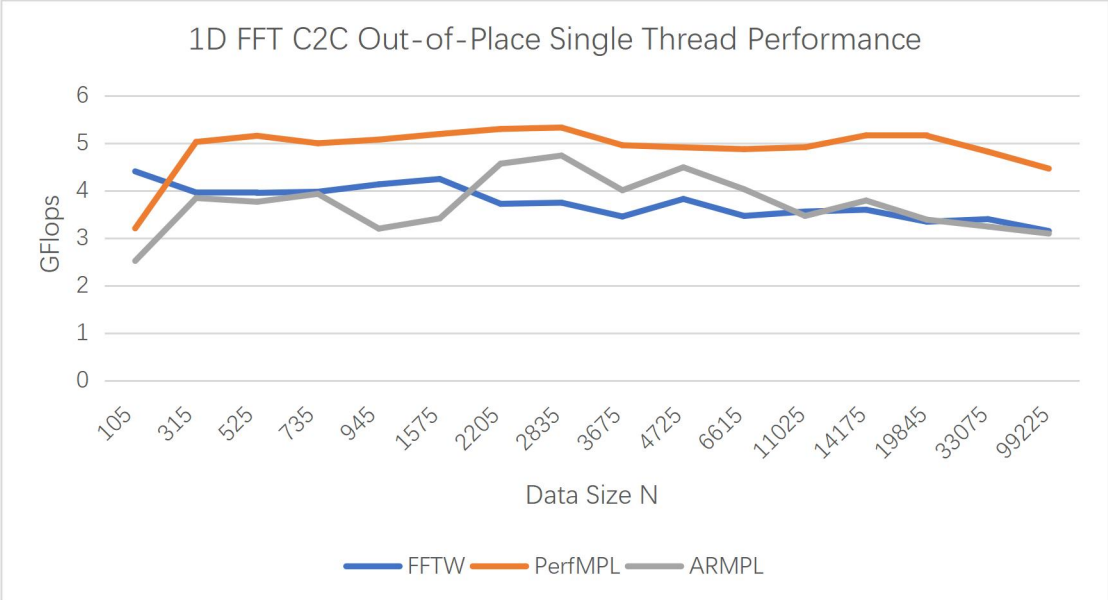


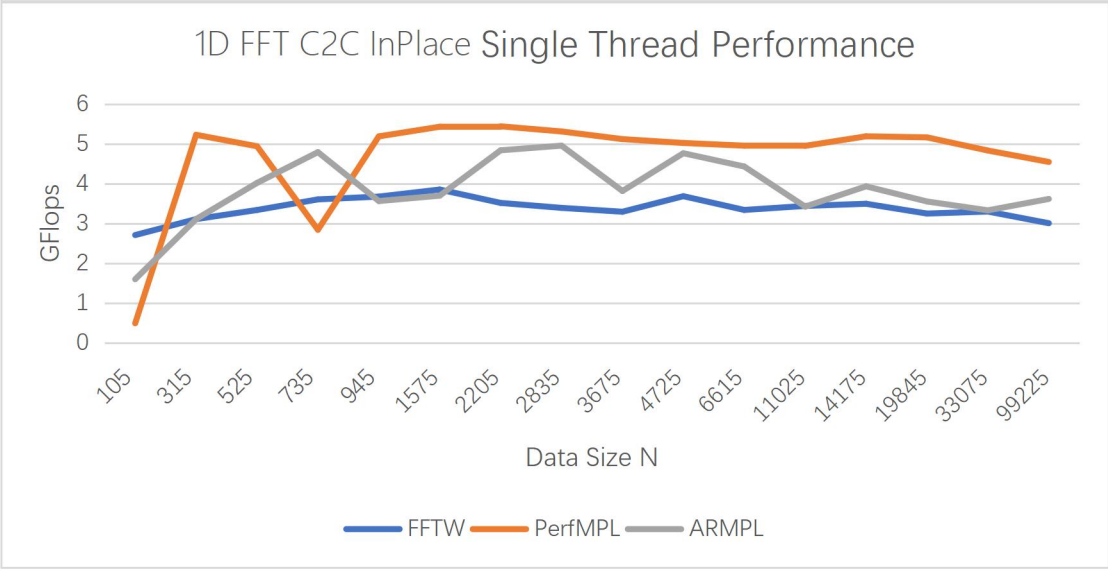
Figure 3（ARM Huawei Kunpeng 920）

2. FFT part performance test (float precision)

Hardware Environment: FT-2000（ARM）

Compare Software: PerfMPL, 1.0.0
FFTW, 3.3.9
ARMPL, 22.0.0





PerfMPL for Dedicated Computing Power

The special-purpose computing power represented by GPU has increased hardware performance by about 50% every year. In some popular fields, with the development of computing software stack technology (domain programming language, computing framework, computing library, etc.), the overall computing performance is more than Moore The law develops rapidly.

The computing library of "PerfMPL for special-purpose computing power" helps computing hardware such as GPU to move towards general-purpose computing power scenarios; need.

The dedicated computing power referred to in this article is mainly provided by the following types of non-general computing power processors:

1. Graphics Processing Unit (GPU)
2. Neural-network Processing Unit (NPU)
3. Field Programmable Gate Array (FPGA)
4. Domain Specific Architecture (DSA)

Looking back at the process of GPU from graphics computing to scientific computing, in order to enable GPU to perform some general-purpose computing, in addition to using the Domain Specific Language (DSL) for GPU programming, it is also necessary to provide at least two supporting standards, BLAS and FFT With the rise of deep learning algorithms and the birth of new research paradigms of AI for Science, the industry has further proposed to support heterogeneous computing platforms DNN library (Deep-Learning Neural Network) library, Sparse library (sparse matrix), etc. demand. The following schematic diagram illustrates the relationship between PerfMPL's necessary computing libraries, scientific computing and artificial intelligence application scenarios for non-general computing processor platforms.

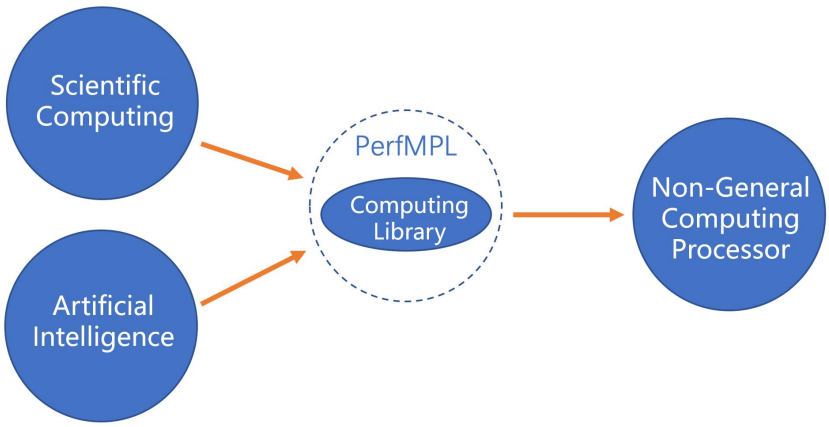


Figure 4

The core mathematical library of "PerfMPL for special-purpose computing power" is related to various factors such as the computing generalization ability of the corresponding special-purpose processor and the computing efficiency of parallel optimization. and FFT are still essential components, as follows:

No.	Library Name	Describe	Applicable Scene
1	PerfBLAS_?	Basic Linear Algebra Subprograms that support a special-purpose processor	Vector-Vector Operations Vector-Matrix Operations Matrix-matrix operations
2	PerfFFT_?	Fast Fourier Transform library that supports a special-purpose processor.	C2C, C2R, R2C, R2R transformation of FFT
3	PerfDNN_?	A deep learning operator library that supports a dedicated processor, including inference and training operators	Deep Learning Inference and Training
4	Other include libraries are defined on demand		

The figure on the right illustrates the location of PerfMPL (mathematical library) in the dedicated computing power software stack.。

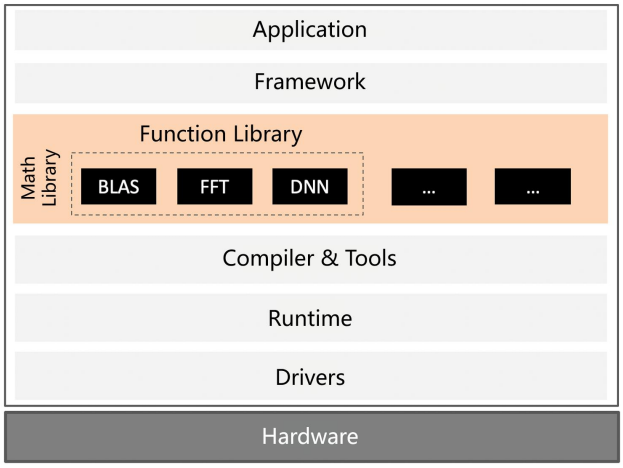


Figure 5

Achieve Ecological Win-Win and Open the Era of Computing Power

In the digital economy, computing power has become a new key productivity and an important indicator to measure the development level of a country's digital economy. The vigorous development of the artificial intelligence industry has promoted the explosive growth of data volume and increasingly diversified data forms, and the demand for diversified computing power has also continued to evolve. Data centers are moving in the direction of heterogeneous computing.

PerfMPL defines a complete and unified computing API interface at the core mathematical library level for diversified computing platforms (CPU, GPU, ASIC, FPGA, etc.), and implements source codes for mainstream CPU instruction sets. This not only reduces repeated investment in the industry, but also provides a unified foundation for the development of advanced computing ecology, and ultimately achieves a win-win situation for the ecology.

PerfMPL continues to deeply understand the demand for computing power in various technical fields and cutting-edge technology exploration, combined with our in-depth understanding of computer architecture, helps various fields and algorithms to achieve computing acceleration at the basic software level, and jointly opens the era of computing power.

The future of the "Metaverse" envisioned by mankind must be built on the basis of computational mathematics, and implemented at the lowest level through software codes such as the PerfMPL mathematical library.

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