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Programming bare-metal accelerators with heterogeneous threading models: a case study of Matrix-3000

Key words: Heterogeneous computing; Parallel programming models; Programmability; Compilers; Runtime systems

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Motivation

1. Heterogeneous many-core processors are now commonplace in computer systems, but the potential of accelerators can be unlocked only if the software can make good use of the hardware.
2. Writing and optimizing code for many-core accelerators is challenging for many application developers, because the current hardware architecture and programming model of accelerators significantly differ from those of the conventional multi-core processors.
3. Our work will focus on addressing the programming issues of Matrix-3000 and similar accelerators.

Main idea

1. We share our experience of designing and implementing a programming model and its supporting compiler and runtime system for the Matrix-3000 (also coined as MT-3000) heterogeneous many-core accelerator.

Method

1. To support software development for MT-3000, we have developed a piece of full-stack system software from scratch, where we focus on two programming modules: the hthreads low-level programming interface and the MOCL3 OpenCL compiler.

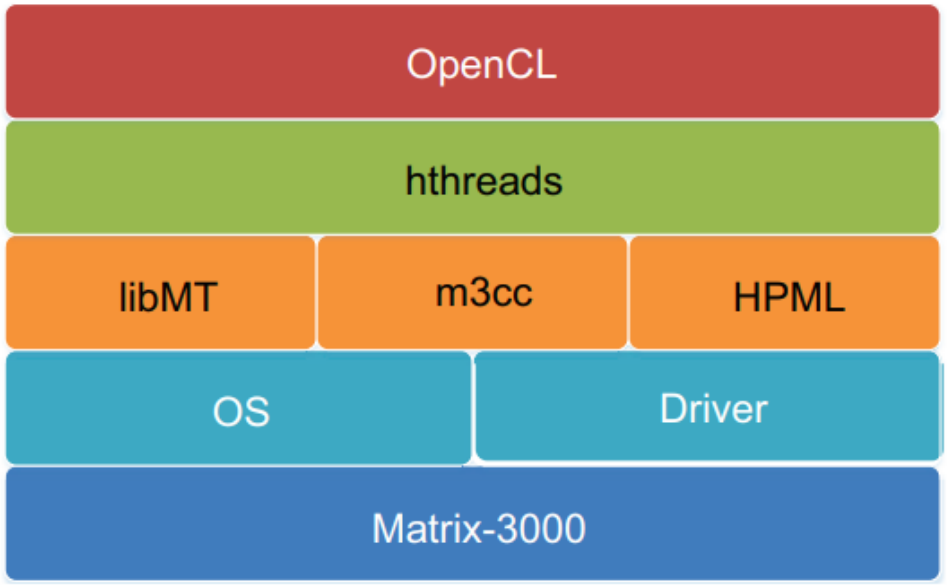


Fig. 3 The MT-3000 programming stack (OS: operating system)

Method (Cont'd)

2. We develop a low-overhead high-availability heterogeneous programming interface (hthreads). At the core of hthreads is a heterogeneous threading model introduced for the bare-metal MT-3000 accelerator.

- The hthreads interface consists of the general-purpose (GP) zone side application programming interfaces (APIs) and the acceleration (ACC) zone side APIs.
- hthreads exposes as many performance-related architecture features as we can, aiming to fully tap its computing potentials.
- We introduce the threading model to hide the metal-related uses such as the native direct memory access (DMA) usage.

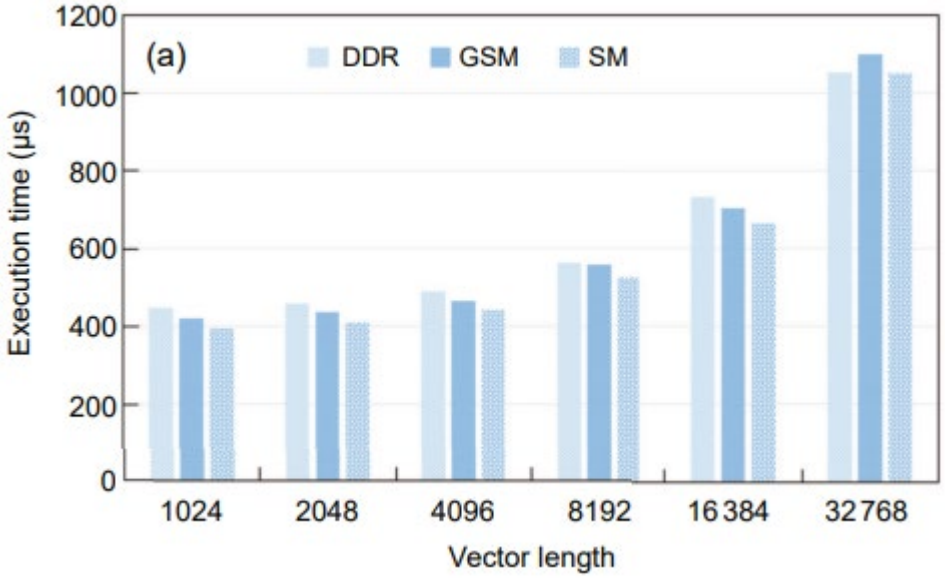
Method (Cont'd)

3. At a higher level, we provide the implementation of the OpenCL standard parallel programming interface (MOCL3) for the MT-3000 architecture.

- MOCL3 follows the programming specification of OpenCL 1.2.
- While ensuring to explore the computing potential of MT-3000, MOCL3 can be effectively compatible with OpenCL legacy code and significantly improve programmability.

4. With these two programming interfaces, we aim to achieve a balance among performance, programmability, and portability for our bare-metal accelerator.

Major results



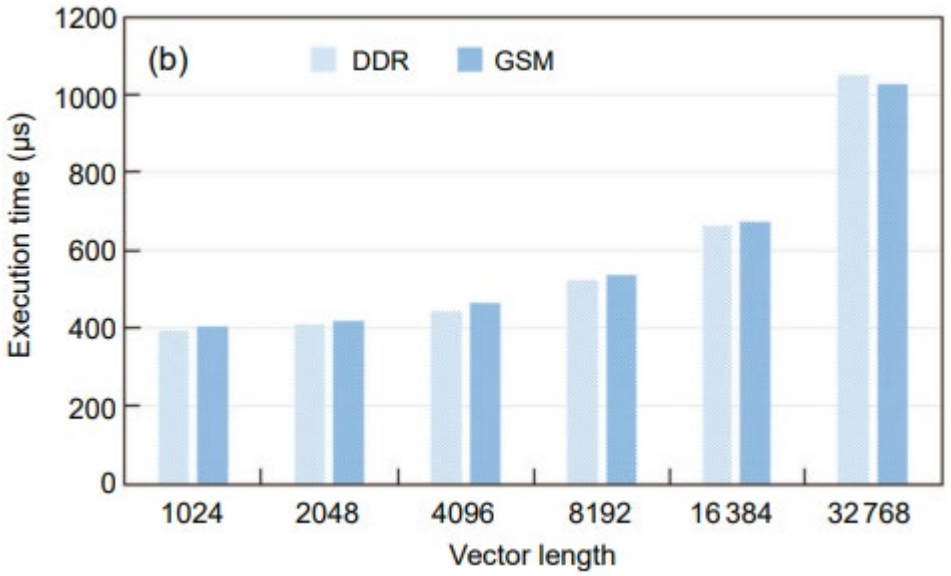


Fig. 10 Performance comparison of different design choices: (a) memory layout (the performance obtained from placing stack on SM over DDR and GSM); (b) code layout (performance comparison between placing code on DDR and GSM). SM: scalar memory; DDR: double data rate; GSM: global shared memory

Major results (Cont'd)

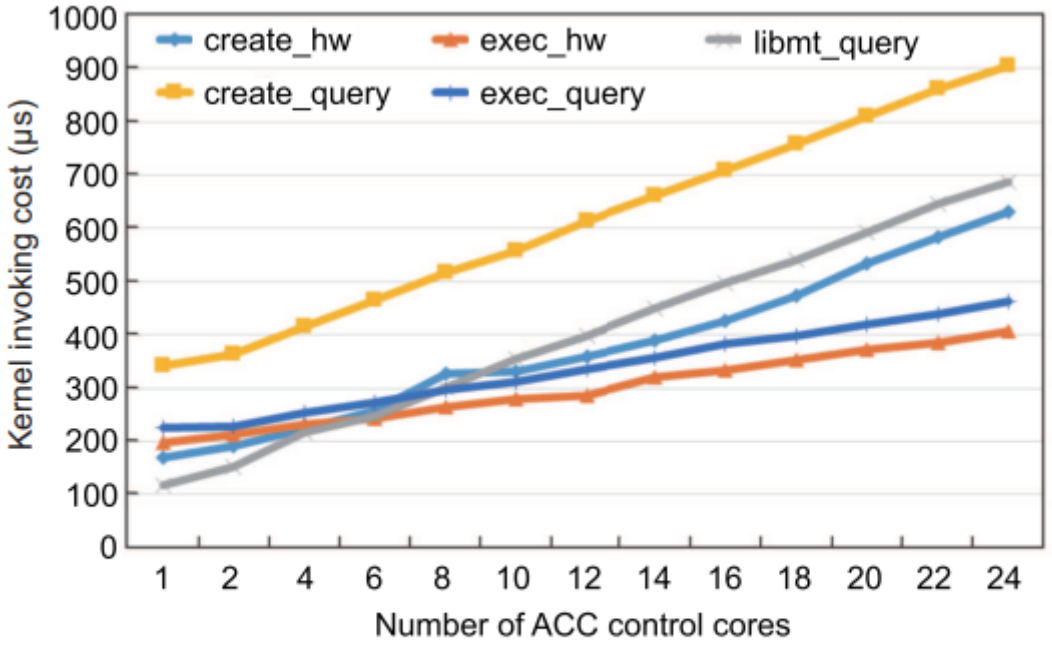


Fig. 11 Invoking cost of using hardware interrupt over querying

Major results (Cont'd)

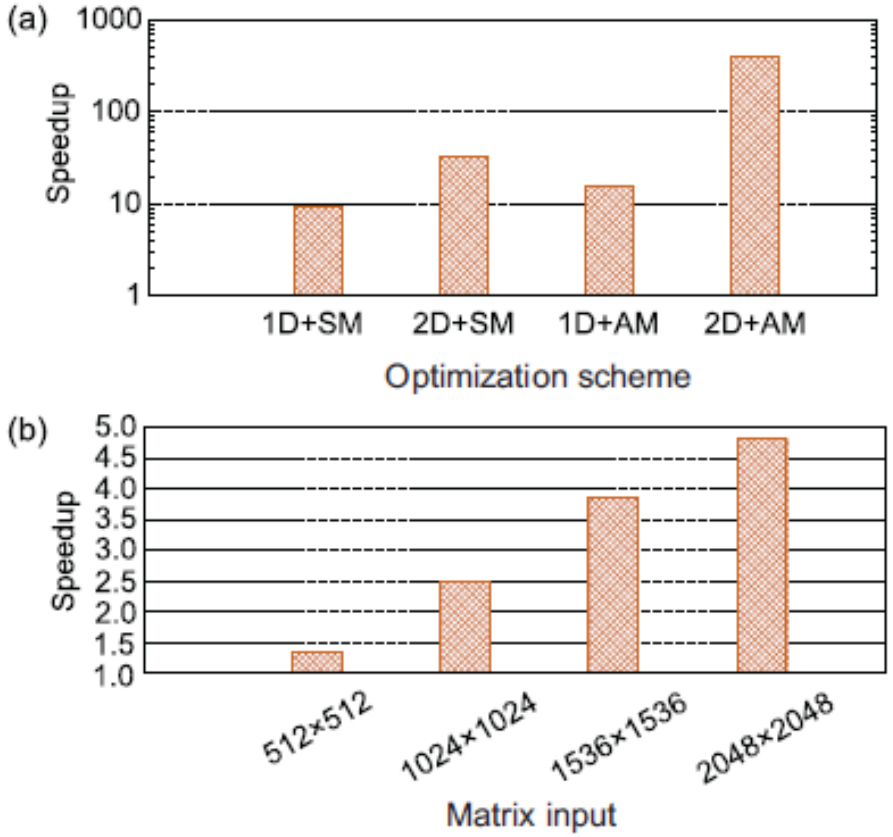


Fig. 12 Speedup over baseline implementations for matrix multiplications: (a) with various optimizations in hthreads; (b) with local memory in MOCL3

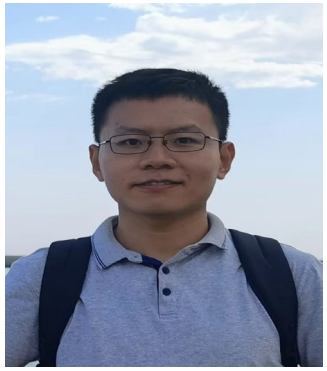
Conclusions

1. We have presented the design and implementation of the programming and compiler tools for the Matrix-3000 accelerator.

2. Given the complex memory hierarchy and processor core organization of Matrix-3000, the use of microarchitecture design in a way that enables complete realization of potential hardware performance depends on the effectiveness of the customized software employed on the device.

3. We share our experience on how a low-level threading-based programming interface can be developed to support the high-level OpenCL programming standard.

Jianbin FANG is an assistant professor in computer science at National University of Defense Technology (NUDT). He received his PhD degree from Delft University of Technology in 2010. His research interests include parallel programming for many-cores, parallel compilers, performance modeling, and scalable algorithms. He is a member of CCF.



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